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ILLUSTRATIONS OF THE METHODS OF REASONING

ILLUSTRATIONS OF THE METHODS OF REASONING

A SOURCE BOOK IN LOGIC AND SCIENTIFIC METHOD

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BY

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D. APPLETON AND COMPANY

NEW YORK :: 1927 :: LONDON

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PREFACE

An applied logic is in the making. Teachers are coming more and more to recognize that beginning students must approach logical theory through a study of thinking in the concrete. This book aims to facilitate this "project" or "case" method of teaching logic by making available an adequate supply of fresh, interesting, and simple illustrations of each of the methods of reasoning now being so fruitfully employed in scientific research. To make the book comprehensive a chapter of examples of the various processes of the traditional Aristotelian logic has been included. The brief expositions of the methods, together with the reading lists which follow them, constitute a syllabus which the teacher can expand as best suits his own purpose. The instructions to students, like the special questions following many of the illustrations, aim merely to provoke thought and to suggest specific tasks for the student, and they also may be modified in any way that seems best to meet the needs of a particular class.

Although I have followed the general plan of organization of my *Principles of Reasoning*, the book is readily adapted to use with any other logic textbook. Or it may be used in lieu of a text by teachers who use the lecture method of instruction or who prefer to have students consult various texts. The book is primarily intended for teachers and students of logic and scientific method, but teachers of general-science courses in high schools, of orientation courses for college freshmen, and of the methods of teaching science in normal schools and departments of education may find these illustrations serviceable in stimulating student interest in the methods of scientific research. The book might also furnish a basis for courses in the methods of reasoning or applied logic in evening schools and for correspondence and extension courses.

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Most of the classical literature on methodology is beyond the powers of comprehension of the average beginning student. This is not true of the two appendices, John Stuart Mill's exposition of the experimental methods and John Tyndall's famous address entitled "The Scientific Use of the Imagination." These two great classics can be read with pleasure and studied with profit by anyone interested in scientific method, and they are reprinted here in the hope that they may thereby become more widely known.

My thanks are due to my colleagues Dr. G. B. Phillips and Mr. R. J. Van Tassel, to the former for supplying me with many of the examples in Chapter I, and to the latter for helping to prepare the chapter on statistics. I am especially indebted to Mr. John Benn, editor of *Discovery*, for permission to use the numerous selections drawn from that magazine. I wish also to acknowledge with sincere thanks the courtesies of other authors, editors, and publishers, including especially my own publishers and the director and the managing editor of *Science Service*, in granting me permission to use copyrighted material.

D. S. R.

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ILLUSTRATIONS OF THE METHODS OF REASONING

CHAPTER I

TRADITIONAL ARISTOTELIAN LOGIC

Aristotle (384-322 B.C.) is known as the father of logic. He was the first to bring together and to systematize previously discovered material, and he also worked out in detail the type of reasoning known as syllogistic reasoning. Every comprehensive textbook in logic devotes considerable space to the exposition of those logical processes constituting the body of Aristotelian logic. Some writers call traditional logic *deductive* in contrast to the *inductive* logic. But since scientific methods also make use of deduction, it seems best to use the name *Aristotelian logic* for the old logic and *scientific method* for the new. It is customary to classify the material of Aristotelian logic under five main headings.

A. *Terms*

Distinctions are made between *concrete* and *abstract; singular, general* and *collective; absolute* and *relative;* and *positive* and *negative* terms. The meaning of the intension or connotation and of the extension or denotation of terms, and the problem of the definition of terms are other important matters which come up for consideration. Here, too, are usually included some account of the categories and the predicables, both of which may be regarded as very general classes.

B. *Propositions*

In order to deal with statements in the precise and accurate manner required by Aristotelian logic they must first be ex-

pressed as single propositions or judgments. Propositions are classified into *conditional* and *categorical*, the former including *hypothetical* and *disjunctive* propositions. The hypotheticals usually take the form, "If x is y then z is w," the first element being known as the *antecedent* and the second as the *consequent*. Disjunctive propositions are usually of the form, "Either a is b or c is d," each element being known as an *alternative*. There are four important types of categorical propositions: (1) the *universal affirmative*, "All politicians are tactful," symbolized by the letter *A;* (2) *universal negative*, "No politicians are tactful," symbolized by the letter *E;* (3) *particular affirmative* "Some politicians are tactful," symbolized by the letter *I;* (4) *particular negative*, "Some politicians are not tactful," symbolized by the letter *O*. A term is *distributed* in a proposition when it refers to all of its members or is used in its complete extension, and it is *undistributed* when it refers to only a part of its members or is used in part of its extension. Symbolizing the subject and predicate of a proposition with the letters *S* and *P*, the following table indicates the distribution of each term in each of the four categorical propositions:

TABLE I

A.	*S* dis.	*P* undis.
E.	*S* dis.	*P* dis.
I.	*S* undis.	*P* undis.
O.	*S* undis.	*P* dis.

The operations on propositions are known as *immediate inferences*. There are five of these: (1) *opposition*, (2) *obversion*, (3) *conversion*, (4) *contraposition*, and (5) *inversion*. Such processes are usually confined to categorical propositions, but they cannot be applied until the proposition is put into *logical form*, that is, expressed as one of the four types of categorical propositions just differentiated and symbolized by the letters *A, E, I* and *O*. Hence the reduction of statements to logical form is an indispensable prerequisite to the performing of these five immediate inferences, but it is also a valuable mental discipline.

C. *Syllogisms*

A syllogism is a piece of reasoning in which a proposition called the *conclusion* is reached by a preliminary comparison of each of its two terms, S and P (S being the symbol for the subject and P for the predicate of the conclusion) with another term, known as the *middle term* and symbolized by the letter M, the two propositions in which the respective comparisons are made being known as *premises*. S is the *minor* and P is the *major* term. That proposition which compares the major term with the middle term (M is P or P is M) is called the *major premise*, and that proposition which compares the minor term with the middle term (M is S or S is M) is called the *minor premise*. For example:

Major premise: All who are capable of handling the masses of the people are tactful.
Minor premise: All politicians are capable of handling the masses of the people.
Conclusion: All politicians are tactful.

The *mood* of a syllogism is determined by the quantity and quality of the three propositions and is designated by the appropriate symbols. Thus in the example just given it is *AAA*, but it could be *EAE*, *EIO*, *et cetera*, depending on the particular combination of symbols in each case. There are sixty-four possible moods, nineteen of which are valid. The *figure* of a syllogism is determined by the position of the middle term in the premises. Since four different positions are possible, there are four figures:

Fig. I	Fig. II	Fig. III	Fig. IV
M is P	P is M	M is P	P is M
S is M	S is M	M is S	M is S
S is P	S is P	S is P	S is P

There are eight rules by which the validity of a syllogism is determined. The following classificatory scheme contains these rules and the names of the fallacies which result when they are violated:

I. *Rules of Structure*

1. A syllogism must contain three, and only three, propositions.
Fallacy: four propositions.

2. A syllogism must contain three, and only three, terms. *Fallacy:* four terms. Ambiguous middle is the usual form of this fallacy.

II. *Rules of Quantity*

3. The middle term must be distributed in at least one premise. *Fallacy:* undistributed middle.
4. No term can be distributed in the conclusion which was undistributed in its premise. *Fallacies:* illicit major and illicit minor.

III. *Rules of Quality*

5. A valid conclusion cannot be drawn from two negative premises. *Fallacy:* two negative premises.
6. If one premise is negative the conclusion must be negative, and if the conclusion is negative one premise must be negative. *Fallacies:* affirmative conclusion from a negative premise and two affirmative premises with a negative conclusion.

IV. *Corollaries*

7. No conclusion can be drawn from two particular premises. *Fallacies:* undistributed middle and illicit major.
8. If one premise is particular the conclusion must be particular. *Fallacies:* undistributed middle, illicit major, illicit minor, or two negative premises.

The special rules of the separate figures are listed below (page 32). They are really corollaries of the general rules. By using the immediate inferences referred to above it is possible to change the valid moods of the second, third, and fourth figures into those of the first figure. This process is known as *reduction.*

D. *Irregular Arguments, Hypothetical and Disjunctive Syllogisms, and Dilemmas*

The so-called *irregular arguments* include *enthymemes*—a syllogism with a suppressed premise or conclusion and hence violating the first rule; *chains of reasoning* and the *sorites,* which is a special chain of reasoning in the first figure; and valid arguments violating the second rule of the syllogism, or having four terms. *A fortiori* arguments are the most important of this last type.

Hypothetical syllogisms may be either *pure* or *mixed.* When pure they contain three hypothetical propositions, and

when mixed the major premise is hypothetical, the minor either affirms or denies the antecedent or consequent of the major categorically, and the conclusion either affirms or denies categorically the other element. The mixed hypothetical syllogism is the most common. It may take any one of four forms, only two of which are valid:

Constructive

I. *Affirming the Antecedent* (valid)

If x is y, then z is w.
But x is y,
Therefore, z is w.

II. *Affirming the Consequent* (invalid)

If x is y, z is w.
But z is w,
Therefore x is y.

Destructive

III. *Denying the Antecedent* (invalid)

If x is y, z is w.
But x is not y,
Therefore z is not w.

IV. *Denying the Consequent* (valid)

If x is y, z is w.
But z is not w,
Therefore x is not y.

The *disjunctive syllogism* contains a disjunctive proposition for its major premise and a categorical proposition for its minor premise which either affirms or denies one of the alternatives of the major premise. The conclusion denies the other alternative when the minor affirms, and affirms the other alternative when the minor denies. The major may take the forms, either a or b is c and a is either b or c, instead of the form given below.

I. *Affirming by denying.*

Form A

Either a is b or c is d.
But a is not b,
Therefore c is d.

Form B

Either a is b or c is d.
But c is not d,
Therefore a is b.

II. *Denying by affirming.*

Form A

Either a is b or c is d.
But a is b,
Therefore c is not d.

Form B

Either a is b or c is d.
But c is d,
Therefore a is not b.

Dilemmas combine hypothetical and disjunctive reasoning. They place an opponent in the position of having to accept one or the other of two alternatives, either of which is bad.

These alternatives are called horns, and the opponent is said to be impaled or gored on the horns. A dilemma may be met in three different ways: (1) by taking it by one or the other of its horns, that is, by accepting the alternative but denying that it leads to the assumed bad consequences; (2) by escaping between the horns or setting up a third alternative; and (3) by constructing a counter dilemma to refute the one of your opponent. The various forms of the dilemma can best be represented by symbols:

I. *Simple Constructive*

If a is b, c is d, and if e is f, c is d.
But either a is b or e is f,
Therefore c is d.

II. *Simple Destructive*

Form A

If a is b, c is d and e is f.
But either c is not d or e is not f,
Therefore a is not b.

Form B

If a is b, either c is d or e is f.
But c is not d and e is not f,
Therefore a is not b.

III. *Complex Constructive*

If a is b, c is d, and if e is f, g is h.
But either a is b or e is f,
Therefore either c is d or g is h.

IV. *Complex Destructive*

If a is b, c is d, and if e is f, g is h.
But either c is not d or g is not h,
Therefore, either a is not b or e is not f.

E. *Fallacies*

The fallacies of the syllogism, listed with the rules above, are known as *formal fallacies*. There are a number of other fallacies dealt with in traditional logic, most of which were explained by Aristotle in his famous treatise on fallacies entitled *Sophistical Difficulties*. Some of these are called *verbal*

and some *material fallacies*. The terms *sophism* and *paralogism* are synonyms for fallacy. A list of the chief fallacies not already enumerated, with a brief definition of each, follows.

1. *Amphiboly* is a statement capable of two different interpretations. It is an ambiguous proposition rather than an ambiguous term.
2. *Accent* is the fallacy resulting when a word, phrase, or even an entire sentence in a passage quoted is overemphasized or misconstrued, either by the way it is spoken or written (for example, in italics), thus giving a false notion of the speaker or writer's intended meaning.
3. *Composition* is assuming that something is true of a collective whole which is true only of the individual members taken separately.
4. *Division* is the reverse of composition, that is, assuming something to be true of the individual members which is true only of the collective whole.
5. *Accident* is the fallacy which results when accidental features of an object are treated as essential.
6. *Petitio principii* or *begging the question* is assuming the conclusion which is to be proved and making it a part of the premises used to prove it. John Stuart Mill claimed that every syllogism begs the question because the major premise always contains the conclusion.
7. *Vicious circle* or *circulus in probando* is a special form of begging the question and consists in using two equally unproved assumptions to prove each other.
8. *Complex question* is a question containing an assumption and the answering of which forces one to accept the assumption. This is also a special form of begging the question.
9. *Irrelevant conclusion* is drawing a conclusion which is not germane to the real point at issue or is not *ad rem*. This fallacy takes several forms.

   (*a*) *Argumentum ad hominem* is a conclusion about the person advancing a thesis instead of one about his thesis.

   (*b*) *Argumentum ad populum* or *Argumentum ad misericordiam* are appeals to popular prejudices, sentiments, and sympathies, instead of relying on an appeal to reason alone.

(*c*) *Argumentum ad verecundiam* is the appeal to the authority of some distinguished person or institution.

(*d*) *Argumentum ad ignorantiam* is the attempt to prove a theory by showing that its opposite is absurd.

10. *Non-sequitur* is a conclusion which is not only irrelevant but does not even follow from the premises.
11. *False assumption* is the fallacy of basing an argument on a covert or hidden false assumption. Such fallacies usually take the form of the enthymeme or syllogism with a suppressed premise. This fallacy is hardly distinguishable from begging the question.
12. *False cause* or *post hoc ergo propter hoc* is assuming that one event is the cause of another for the reason that the former preceded the latter in time, the Latin phrase meaning—after this, therefore because of this.

WHAT TO READ

The above sketch of traditional logic is intended merely as a framework on which to hang the examples which follow. The student should read a more extended account of each process before attempting to answer the questions. Any of the following books will be found satisfactory, but those marked with an asterisk (*) are the most recent. It is recommended that students be required to buy one book and that copies of the others be kept on reserve in the reading room of the library.

Aikins, H. A., *Principles of Logic.*
Creighton, J. E., *An Introductory Logic,* 4th edition.
*Cunningham, H. E., *Textbook of Logic.*
*Dotterer, R. H., *Beginner's Logic.*
Gibson, W. R. B., *The Problem of Logic.*
Hibben, J. G., *Logic, Deductive and Inductive.*
Jevons, F. B., *Elementary Lessons in Logic.*
Jones, A. K., *Logic, Inductive and Deductive.*
Joseph, H. W. B., *An Introduction to Logic.*
Keynes, J. N., *Studies and Exercises in Formal Logic.*
Mellone, S. K., *An Introductory Textbook in Logic.*
*Robinson, D. S., *The Principles of Reasoning.*
Schiller, F. C. S., *Formal Logic.*
*Sellars, R. W., *The Essentials of Logic,* 2nd edition.
*Templin, O., *A Guide to Thinking.*
Welton, J., *Manual of Logic,* Vol. I.
Welton and Monahan, *An Intermediate Logic.*

A. Terms

I. *Concrete and Abstract.*—In the first meaning a term is concrete which denotes a sense object or quality and one is abstract which denotes a nonsensuous object or entity. In the second sense a term is concrete when it is taken in its proper context or in the system to which it naturally belongs, whereas it is abstract when treated apart from this system.

Show how each of the following terms are abstract or concrete according to (*a*) the first meaning of these expressions, (*b*) the second meaning:

1. Medal
2. The moon
3. Miami University
4. Time
5. List of candidates
6. Sweetness
7. Nobility
8. The square root of two
9. Walnut
10. Flavor
11. Armor
12. Heaven

II. *Singular and General.*—Singular terms are those denoting only one object and general terms are those denoting more than one.

Use each of the following nouns with modifiers (if necessary) in a sentence in such a way that the term of which it is a part is (*a*) singular, (*b*) general:

1. Lincoln
2. Clock
3. Brother
4. James
5. Beauty
6. Inference
7. Reward
8. Home
9. Corporation

III. *Distributive and Collective.*—Distributive terms are the same as general. Collective terms are those referring to a group of individuals or members instead of referring to the members of the group taken separately.

Use each of the following collective terms in (*a*) a general sense, (*b*) a singular sense:

1. Insurance company
2. Football team
3. Family
4. Flock
5. Kingdom
6. Library

(1) Use each of the following collective terms singularly in a sentence.

(2) Make a second set of sentences (using new terms if necessary) making statements about the members of the same groups taken distributively.

1. Student body
2. Choir
3. Peck of potatoes
4. Forest
5. Fraternity
6. Supreme Court

IV. *Absolute, Relative and Correlative.*—Absolute terms are the names of objects capable of being thought of alone or without the help of another term. A correlative term depends on another, called its *correlate.*

Examine each of the following terms and tell whether it is relative or absolute. What would be the correlate of each correlative term?

1. Answer
2. Coachman
3. Dominant trait
4. Interferometer
5. Tiger
6. Memorial
7. Servant
8. Knight

V. *Positive and Negative.*—Positive terms are those which refer to the qualities constituting the object or entity named. Negative names are those referring to everything not constituting the object or entity. The infinite negative refers to everything else in the world except what is included under the corresponding positive term. To get a limited negative we restrict ourselves to a definite field of thought. Then the negative refers only to all other objects in this restricted *universe of discourse* which are not included in the corresponding positive term.

(1) Give the contradictory of each of the following terms.
(2) State a universe of discourse in which each term might be used and give the natural negative term within that universe.

1. Wise man
2. Right way to use a mashie
3. Number greater than ten
4. The only woman in the world
5. Republicans who voted for Coolidge
6. Freshmen
7. Even-numbered seats
8. Space
9. Radio
10. Speedometer
11. Phi Beta Kappa students
12. Textbook

VI. *The General Terms Known as Categories.*—A category is the most general kind of existence any entity can have. Aristotle recognized ten different categories, as follows: substance, quality, quantity, relation, place, time, state or condition, situation, passivity and activity. Some logicians claim that certain of these are reducible to others. Which do you think might be so reduced?

Put each word in the following passages in its proper Aristotelian category, that is, tell whether it indicates a substance, quantity, quality, relation, or *et cetera:*

1. Steaming full speed ahead the battleship ran rapidly past the target firing a salvo from her ten sixteen-inch guns. The target was riddled by the shells and the broken pieces of lumber could be seen floating in the ocean.
2. The angel Israfel, whose heart-strings are a lute, has the sweetest voice of all God's creatures. (*Koran.*)
3. If I could dwell
   Where Israfel
   Hath dwelt, and he where I,
   He might not sing so wildly well
   A mortal melody,
   While a bolder note than this might swell
   From my lyre within the sky. (Edgar Allan Poe.)
4. The man of science who believes in God need not accept any form of religion, nor require for his satisfaction any system of symbolism or personalization, but may, nevertheless, cordially accept the eternal verity of a directing principle in nature. (J. G. Adami.)
5. It is one thing to know what cause means in the cheap sense of being able to understand intuitively such an assertion as that the Santa Barbara earthquake caused the collapse of numberless chimneys; and it is another and a much more difficult and rarer thing to know what cause means in the sense of being able to give a correct definition of it. (C. J. Ducasse.)
6. A deeper music in the strain
   Of hermit-thrush from lonely tree;
   And deeper grows the sense of gain
   My life has found in having thee. (Henry Van Dyke.)

VII. *Intension and Extension.*—The intensive meaning of a term is all of the qualities essential to constitute the kind of entity referred to by that term. A synonym is connotation. The extensive meaning is all or any of the actual entities having these qualities and a synonym is denotation. Every term connotes certain definite qualities and at the same time denotes specific objects having those qualities. The intension of a term may be increased by adding other qualities than those included in the term. For example, the intension of the term *man* is increased by adding *educated,* but its extension is decreased.

1. Indicate first the intension and then the extension of each of the following terms:

(*a*) Political party
(*b*) Scandinavian
(*c*) Snare
(*d*) Germ
(*e*) Water
(*f*) Course of history
(*g*) Airplane
(*h*) Telescope
(*i*) Rings of Saturn
(*j*) Coolidge family
(*k*) Elk

2. Increase the intension of the following. How is the extension affected in each case?

(*a*) Fruit
(*b*) Hunter
(*c*) Postage stamp
(*d*) Parallelogram
(*e*) Associate of the Royal Scottish Academy
(*f*) Letter *M*
(*g*) Uncle
(*h*) Ornithology

3. How far is the statement, "intension and extension vary in inverse ratio," true of the following sets of terms?

(*a*) Dementia, insanity, lunacy, disease, state of health.
(*b*) Building, public building, post-office, New York City post-office.
(*c*) Newfoundland, dog, canine, carnivore, mammal, vertebrate, animal, organism, substance.
(*d*) My desk, office desk, desk, piece of furniture, manufactured object, natural object.

4. Arrange the following terms in series as in question 3, placing each term of greater extension after a term of lesser extension, pointing out which are the terms of greatest and least extension in each series:

(*a*) Number, plant, square, immaterial object, animal, protophyta, rectangle, insect, David Copperfield, plane figure, integer, material object, hymenopteran, living being, quadrilateral, book, metazoa, four, inorganic being, arthropod, novel, geometrical form, artifact.

VIII. *Definition of Terms.*—In defining terms the Aristotelian predicables are used. These are the most general relations a predicate can have to its subject. Five were recognized by Aristotle—genus, species, definition, property, and accident. The last two are the nonessential aspects and they should not be included in a definition. The first two constitute the third or definition. Hence defining in the Aristotelian sense is naming the nearest genus and listing the differentiae of the species. One may also define by the *genetic method,* that is, by telling how the thing being defined originated or is constituted or constructed.

There are five rules of definition. (*a*) State all of the essential attributes of the thing to be defined. (*b*) The name to be defined or a synonym for it must not be used in the definition. (*c*) The definition must be exactly equivalent to the class of objects defined, that is, it must be neither too broad nor too narrow. (*d*) Do not use obscure, figurative, or ambiguous language in a definition. (*e*) When at all possible the definition should be affirmative rather than negative.

1. Define the following terms by the Aristotelian method:

(*a*) Twelve	(*e*) Loyalty	(*i*) A straight line
(*b*) College	(*f*) Goat	(*j*) Water
(*c*) House	(*g*) Logic	(*k*) Recompense
(*d*) Divorce	(*h*) Category	(*l*) Essay

2. Define the following terms by the genetic method:

(*a*) A perpendicular line	(*d*) Necktie	(*g*) Wave
(*b*) A musical discord	(*e*) Maple syrup	(*h*) Map
(*c*) Triangle	(*f*) Arithmetical average	(*i*) Smoke

3. Test the following definitions by the five rules of definition:

(*a*) A sense of humor is a wedge to open the way for common sense to do its work.
(*b*) A swindler is a laborer who cheats his employer.
(*c*) The church is the executor of the will of Christ.
(*d*) Learning is the modification of behavior.
(*e*) The glory of life is neither to be loved nor to be served.
(*f*) A good character is a noble possession within the reach of every man.
(*g*) The laity are the people as distinguished from the clergy.
(*h*) Salt is what makes a potato taste bad when you don't put any on.'
(*i*) Language is those articulate sounds by which men express their thoughts.
(*j*) To paraphrase is to give an explanation of an author's meaning.
(*k*) Prosperity is that state in which things succeed according to our wishes and are productive of affluence and ease.
(*l*) Slander is any false utterance against a neighbor.
(*m*) Vinegar is an acid produced by fermentation.
(*n*) Wages are the reward for services performed.
(*o*) A centurion was a Roman military officer who did not command large numbers of men.
(*p*) A demoniac is a person affected by a demon.
(*q*) An eclipse is a failure of light.
(*r*) A furnace is a place for melting gold and other metals.
(*s*) A gap is a breach made in a dam or hedge.

(*t*) Kindred are a number of people akin to one another by blood or marriage.

(*u*) Society is not a community of classes with varying functions, united to each other by mutual obligations arising from their relations to a common end.

4. Select from each of the following sets of definitions the definition you think is the best and explain why you so regard it. Mention one defect in each of the other definitions in the set.

(*a*) *Usury.*

Usury is the unfair business in which men are engaged who do not like to work.

Usury is a summary name for all kinds of extortions.

Usury is any bargain in which one party gains more advantage than the other.

Usury is the gain taken for the loan of money or wares.

Usury is charging a fee for the use of money.

(*b*) *Religion.*

Religion is the serious and social attitude of individuals or communities toward the power or powers which they conceive as having ultimate control over their interests and destinies.

Religion consists in the feeling of absolute dependence.

Religion is the belief in spiritual beings.

Religion is the sentiment of duty as based upon divine command.

Religion is an experience of groups of individuals resulting from their collective and coöperative efforts to secure and preserve the ideals which appeal to them as possessing the greatest value.

Religion is the mediated consciousness possessed by the finite divisible Ego of its dialectical destiny as infinite indivisible Ego.

Religion is the chicanery of priests.

Religion is a spiritual experience distinct from the æsthetic, logical, and ethical.

(*c*) *Life.*

Life is a uselessly interrupting episode in the blissful repose of nothing.

Life is the full smooth-running exploitation of the whole machine to the daily satisfaction of the mechanic.

Life is the continuous adjustment of internal to external relations.

Life is that type of existence which distinguishes plants and animals from inanimate objects.

Life is a chemical process which is self-perpetuating.

Life is that condition in which animals and plants exist with capability of exercising their natural functions.

Life is the interval of existence between birth and death.

IX. *Logical Division*

Read the exposition of classification or logical division at the beginning of Chapter II.

Point out the fallacy in each of the following divisions:

1. Students may be divided into freshman, sophomores, letter men, and members of Phi Beta Kappa.
2. Airships may be divided into monoplanes, biplanes, and zeppelins.
3. Members of the solar system may be divided into planets and non-planets.
4. Mushrooms may be divided into edible and inedible species.
5. College athletics may be divided into inter-collegiate, intramural, and women's athletics.
6. Citizens may be divided into native-born, naturalized, and pro-Germans.
7. Trees may be divided into deciduous trees, evergreens, and fruit-trees.
8. Houses may be divided into brick and non-brick houses.

B. Propositions

I. *The Classification of Propositions*

Arrange the following propositions in the classes (1) hypothetical, (2) disjunctive, and (3) categorical. Designate each categorical proposition by its proper symbol—*A, E, I,* or *O,* and mark the distribution of each of its terms. For distribution see the table above (page 2).

1. All wine is intoxicating.
2. When clouds appear, wise men put on their coats.
3. No wild horses are safe to ride.
4. Either Darwin or Wallace discovered the principle of biological evolution.
5. When a man marries his troubles begin.
6. Some people never trouble trouble until trouble troubles them.
7. If he contracts double pneumonia, he will die.
8. Air is either an element or a combination of elements.
9. All white elephants are regarded as sacred by Buddhists.
10. Some members of the solar system are not planets.
11. If the pig is tied he will squeal.
12. None of the occupants of the coach escaped injury.
13. Either he must consult a physician or his children will become orphans.
14. Some quiet men are criminals.
15. All educated people are individualists.
16. Some publishing houses are not dishonest.
17. If the theory of evolution is true the Biblical account of creation is a myth.
18. Either war must be abolished or civilization will perish.
19. If war is an instrument of social progress, it is beneficial to mankind.
20. No morons are capable of doing college work.

II. *Logical Form of Propositions.*—Before a proposition can be dealt with in formal logic it must be stated so that its quantity and quality are obvious. Many statements in everyday life are ambiguous. It is impossible to tell whether they are universal or particular in quantity and whether they are affirmative or negative in quality. Stating a proposition so that it is unambiguous in both these respects is what is meant by putting it in logical form.

(*a*) Put the following propositions in logical form using what seems to you to be the natural subject and predicate. Designate each proposition by the proper symbol after you get it in logical form.

1. Some dogs have intelligence.
2. Many wild animals hunt by night.
3. Few logicians avoid all errors.
4. It is better to have patience than to have genius.
5. It rains.
6. Not all came to the dance who had been invited.
7. Only when it is warm weather do undergraduates find pleasure in canoes.
8. A few drunken students may bring a whole university into disrepute.
9. To every question there are two answers.
10. Seven cooks can spoil a broth.

(*b*) Put the following propositions into logical form using the term put in parentheses as *subject* term. Designate each proposition by the proper symbol after you get it in logical form.

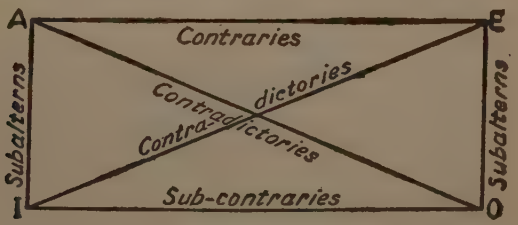
11. Whales are not fishes. (Fishes)
12. Not all uneducated people are selfish. (Unselfish persons)
13. Some lawyers are honest. (Dishonest men)
14. All living beings must take food. (Nonliving beings)
15. Tom and Harry are brothers. (Tom)
16. Care killed a cat. (Cats)
17. Planets move in ellipses. (Ellipses)
18. Knowledge of the material of a course is more to be desired than a good grade. (Good grades)
19. I saw seven men on the road. (Men)
20. When knaves fall out, honest men come into their own. (Times when honest men come into their own)

(*c*) Put the following propositions into logical form using the term put in parentheses as either subject or predicate as seems

best to you. Designate each proposition by the proper symbol after you get it in logical form.

21. It is false that all men have wings. (Men)
22. If wishes were horses, beggars would ride. (Horses)
23. Because it froze last night, the pools are covered with ice. (The condition of pools being covered with ice)
24. In cutting a blade of grass, the locust uses three instruments. (Cuttings of a blade of grass by a locust)
25. Everything that we can do cannot better his condition. (He)
26. It is never wise to believe all that the newspapers say. (Newspapers)
27. Not all recognize that Emerson did much to establish what we mean by "a good American." (Establishing the meaning of the term "good American")
28. The hind heel of a bay mule does not distinguish between the Phi Beta Kappa and the common flunk. (Phi Beta Kappas)
29. The peace of nature and of the innocent creatures of God seems to be deep and secure, only so long as the presence of man is not there to trouble its sanctity. (The presence of man)
30. Wrong as Lincoln thought slavery to be, he considered in 1860 that he could afford to let it alone where it was, because that much was due to the necessity arising from its actual presence in the nation. (The actual presence of slavery in the nation)

III. *Opposition of Propositions.*—Propositions are said to be opposite when they have the same subject and predicate but differ in quantity (*subalterns*), or quality (*contraries* or *subcontraries*), or both (*contradictories*). Singular propositions have only one opposite. The following *square of opposition* makes these relations clear.



Immediate inference by opposition is to assume any of the four to be either true or false and to determine what its three opposites would be. The following tables show these relations:

TABLE II

	A is	*E* is	*I* is	*O* is
If *A* is true	true	false	true	false
If *E* is true	false	true	false	true
If *I* is true	doubtful	false	true	doubtful
If *O* is true	false	doubtful	doubtful	true

TABLE III

	A is	*E* is	*I* is	*O* is
If *A* is false	false	doubtful	doubtful	true
If *E* is false	doubtful	false	true	doubtful
If *I* is false	false	true	false	true
If *O* is false	true	false	true	false

(*a*) Give the opposites of each of the following propositions.

(*b*) Assume the original true and tell what is known about each of the opposites.

(*c*) Assume the original false and tell what is known about each of the opposites.

1. Some Africans are Arabs.
2. Some Arabs are not Asiatics.
3. No Chinese are Europeans.
4. All Eskimos are hunters.
5. The sun is the center of the solar system.
6. Some of the stars form galaxies.
7. Any galactic system is immense.
8. Every politician is friendly.
9. Some wild fruit is not edible.
10. None of these students are members of Phi Beta Kappa.
11. The Kaiser is not living in Germany.
12. All rare books are of interest to collectors.
13. He who is pious is trustworthy.
14. No president has ever held office for three terms.
15. Heaven is not reached by a single bound.

IV. *Conversion.*—The *converse* of a proposition is a proposition having the predicate of the original or *convertend* for its subject and having the subject of the convertend for its predicate. The rule for conversion is: No term can be distributed in the converse which was undistributed in the convertend. Hence the universal *A* proposition converts by

limitation into *I*, the singular *A* converts by simple conversion into *A*, the *E* converts by simple conversion into *E*, and the *I* by simple conversion into *I*, whereas *O* cannot be converted because the undistributed subject of the convertend would have to be distributed, when made the predicate in the converse. Examples will make the process clearer.

		Convertend	*Converse*
		S dis. *P* undis.	
A	*Universal:*	All human beings are fallible.	*I* Some fallible beings are humans.
		S dis. *P* dis.	
	Singular:	The North Star is the nearest star.	*A* The nearest star is the North star.
		S dis. *P* dis.	
E	*Universal:*	No beavers are muskrats.	*E* No muskrats are beavers.
		S dis. *P* dis.	
	Singular:	The moon is not the sun.	*E* The sun is not the moon.
		S undis. *P* undis.	
I	*Particular:*	Some black haws are edible.	*I* Some edible things are black haws.
		S undis.	
O	*Particular:*	Some mythological animals are not centaurs.	*O* Does not convert because one cannot go to all mythological animals from the some which are given in the convertend.
		P dis.	

Convert each of the following propositions. Designate the convertend and the converse by the proper symbol. Write above each term of the convertend its distribution, using the abbreviation *dis.* for distributed and *undis.* for undistributed, as in the examples above. In the case of each *O* proposition explain why it cannot be converted.

1. Some crows are white.
2. Some elephants are not white.
3. The centaur is not a fairy.
4. The White Mountains are not the tallest mountains.
5. All onions are vegetables.
6. No giraffes are animals which dislike onions.
7. Some scientific methods are simple.
8. Some apples are not sour.
9. The Great Dipper is the most conspicuous constellation.
10. All constellations are interesting objects.
11. Heaven is our home.
12. No morons are capable of mastering logic.

V. *Obversion.*—The *obverse* of a proposition is a proposition which says the same thing in the opposite quality to that of the original or *obvertend.* The rule for obversion is: Change the quality of the proposition and substitute for its predicate the opposite term—*non-P* in the case where the predicate is positive and *P* in the case where the predicate is *non-P*

in the original. Thus *A* obverts into *E* and *E* into *A*, *I* obverts into *O* and *O* into *I*. Here are examples of each:

		Obvertend	*Obverse*
A	*Universal:*	All melons are edible.	*E* No melons are inedible.
	Singular:	The Navy is the main arm of our national defense.	*E* The Navy is not that which is not the main arm of our national defense.
E	*Universal:*	No wise men are discourteous.	*A* All wise men are courteous.
	Singular:	The worm is not an attractive animal.	*A* The worm is an unattractive animal.
I	*Particular:*	Some stars are bright.	*O* Some stars are not non-bright.
O	*Particular:*	Some wealth is not transferable.	*I* Some wealth is untransferable.

Obvert each of the following propositions. Designate the obvertend and the obverse by the proper symbol. Designate the quality of the predicate of the obvertend and of the obverse, by writing the symbols *P* or *non-P* above each predicate. Note that the opposite quality can be obtained by prefixing *non* to single words, or by putting *not* within a relative clause where the term is made up of more than one word.

1. All apes are irrational.
2. The wild man of Borneo is a leading attraction of the circus.
3. Some women are highly educated.
4. No rich people are unhappy.
5. Some razors are not safety razors.
6. The Proverbs of Solomon are a part of the wisdom literature of the Bible.
7. Some religions are non-ethical.
8. All buffaloes are quadrupeds.
9. No miracles are probable.
10. The heavens are not what many ancients thought them to be.
11. Sirius is a star which is not single.
12. Some fables are stories about beasts.
13. The story of Ahikar is a fable.
14. Some funerals are depressing.

VI. *Contraposition.*—The *partial contrapositive* of a proposition is the converse of the obverse. The *full contrapositive* is the obverse of the partial contrapositive. Thus *A* obverts into *E*, this converts into the *E* which is the partial contra-

positive and this obverts back into *A; E* obverts into *A*, this converts by limitation into *I* and this obverts into *O; I* obverts into *O* and, since this cannot be converted, *I* yields no partial or full contrapositive; *O* obverts into *I*, this converts into *I* and the *I* obverts into *O* for the full contrapositive. The following forms show these relations: *AEEA, EAIO, IO—, OIIO.*

Take each of the following propositions through the three steps, (1) obvert, (2) convert the obverse to get the partial contrapositive, (3) obvert the converse of the obverse to get the full contrapositive. In the case of the *I* propositions in the list explain why the second and third steps cannot be taken. Designate each proposition by the proper symbol.

1. No United States' presidents have been natives of Utah.
2. Some true stories are uninteresting.
3. Some disobedient children are not punished by their parents.
4. The singing of birds is not uninfluenced by environment.
5. All unripe fruits are unhealthy.
6. No ants are non-segmented.
7. Some houses are built of brick.
8. Some moving-pictures dealing with college students are untrue to campus life.
9. All automobiles traveling the public highways at fifty miles an hour are exceeding the speed limit.
10. No golfer who has not made a hole in one is uninterested in the possibility of so doing.
11. Some people who would not steal a pin are not incorruptible where millions are concerned.
12. All dishonest men are breeders of distrust.
13. Some persons who have had no experience in affairs of state are not hesitant in expressing their opinions on the conduct of government.
14. All birds are animate beings.
15. Some people who have never been to jail are undeserving of their good luck.
16. Some biologists are not uncertain as to what life really is.
17. Some cold days are unfit for tennis.
18. Some logic students are not neat in the preparation of their papers.
19. No ducks are unable to swim.
20. All our sense-organs are insensitive to ultra-violet rays.
21. No contagious diseases are irremediable.
22. All uncertainties are inconvenient.
23. No irreparable disasters are due to nonhuman agencies.
24. Some inconceivable ideas are not impossible.

25. Some people who do not take drugs are not unabnormal.
26. Cæsar was a Roman general who landed in Britain 55 B.C.
27. Some absent-minded men are impractical.
28. No infamous emperors who have not disdained murder to advance themselves have been indifferent to the suspicion of treachery among their followers.
29. No truths are so dangerous as an untruth.
30. No person who has not traveled up the mighty length of the Amazon is able to appreciate the tremendous expanse of tropical jungle which is as yet untamed and untouched by the hand of civilized man.
31. Non-being is not.
32. Some dreams which terrify our mightly hours are traceable to experiences of early childhood.

VII. *Inversion.*—The *inverse* of a proposition is an assertion about the contradictory of the original subject, that is, about *non-S*. The *partial inverse* qualifies *non-S* with the original predicate. The *full inverse* qualifies *non-S* with the opposite of the original predicate. Only *A* and *E* propositions yield the inverse. To get the full inverse from *A* we convert the full contrapositive and to get the partial inverse from *A* we convert the full inverse. Thus:

Original:
All mammals are vertebrates.
Obverse:
No mammals are non-vertebrates.
Converse:
No non-vertebrates are mammals.
Obverse:
All non-vertebrates are non-mammals.
Converse and *Full Inverse:*
Some non-mammals are non-vertebrates.
Obverse of this and *Partial Inverse:*
Some non-mammals are not vertebrates.

To get the inverse from an *E* proposition we begin by converting, then this converse is obverted and the proposition thus obtained is converted into the partial inverse. Obverting this gives the full inverse. Thus:

Original:
No monkeys are invertebrates.
Converse:
No invertebrates are monkeys.

Obverse:
All invertebrates are non-monkeys.
Converse and *Partial Inverse:*
Some non-monkeys are invertebrates.
Obverse of this and *Full Inverse:*
Some non-monkeys are not vertebrates.

Give the partial and full inverse of the following propositions:

1. All animals are sentient beings.
2. No plants are capable of locomotion.
3. All seeds are capable of producing plants.
4. No evergreen trees are valueless.
5. All men are beings who crave salt.
6. No cretins are curable.
7. All Quakers are pacifists.
8. All fadeless dyes are valuable.
9. No rings of Saturn are visible to the unaided eye.
10. No solar rays are unanalyzable.

VIII. *Supplementary Propositions*

(*a*) Put each of the following propositions in logical form and designate its quantity and quality by the proper symbol.
(*b*) Convert each proposition which can be converted.
(*c*) Obvert each proposition.
(*d*) Contrapose each proposition which can be contraposed.
(*e*) Give the inverse of the universal propositions.
(*f*) Give the opposites of each of the first ten propositions.

The following table, from J. N. Keynes, *Studies and Exercises in Formal Logic* (p. 140), may be helpful. *S′* and *P′* are equivalent to *non-S* and *non-P*.

TABLE IV

		A	*I*	*E*	*O*
I	Original proposition	*SaP*	*SiP*	*SeP*	*SoP*
II	Obverse	*SeP′*	*SoP′*	*SaP′*	*SiP′*
III	Converse	*PiS*	*PiS*	*PeS*	
IV	Obverted Converse	*PoS′*	*PoS′*	*PaS′*	
V	Partial Contrapositive	*P′eS*		*P′iS*	*P′iS*
VI	Full Contrapositive	*P′aS′*		*P′oS′*	*P′oS′*
VII	Partial Inverse	*S′oP*		*S′iP*	
VIII	Full Inverse	*S′iP′*		*S′oP′*	

1. There is no wealth but life.
2. Men generally are all for themselves.
3. Moderate interest is not unlawful.
4. Snakes are sometimes equipped with poison fangs.
5. Not all moral values are religious values.
6. Only those who are not indifferent to the goods of the mind can be persuaded that the study of philosophy is not a waste of time.
7. Men sometimes lie.
8. Pearls are not found in every puddle.
9. A wish is father to a thought.
10. Only the profiteers were unpopular.
11. The riddles to be solved were not a few.
12. Few will deny that everything will ultimately right itself.
13. Most things have their price.
14. Nothing but the still small voice that whispers "Fiddlesticks!" can save one from being imposed upon by a propagandist.
15. Rich men are not always to be envied.
16. Poor masonry will not stand against the pull of gravity.
17. To the man with no port every wind is ill.
18. He who refuses to wash his windows need not blame the sunshine for failure to shine through.
19. A hammer is a useless stick when it loses its head.
20. True goodness springs from a man's own heart.
21. Noble men tend upwards.
22. Base men tend downwards.
23. Not all cowards are punished.
24. None but the slothful are total failures.
25. The men who eat most are sometimes gluttons.
26. Not all who have beautiful manners have real refinement.
27. Few in this neighborhood, save the very poor, have never heard a radio.
28. None but those who have kept training rules know what difficulties this discipline involves.
29. All the people who want to go to college are not able to profit by a college education.
30. Only with a pen dipped in blood, has most history been written.
31. "The more of the details of our daily life we can hand over to the effortless custody of automatism, the more our higher powers of mind will be set free for their own proper work." (*William James.*)
32. They say that our team must win.
33. Nobody's thoughtless railing can solve the problems of the honor system.
34. Only those with vigorous personalities can hold an audience for several hours.
35. None but aviators can fully appreciate the accomplishment of Colonel Lindbergh in making a nonstop flight from New York to Paris alone.
36. All American poets of the time, except Whitman, followed Europe.

37. All those who claim to be radicals will not be bold enough to assert their claims when the opportunity comes.
38. Only those who feel their littleness have true grandeur.
39. No living creatures, save human beings, can commit suicide.
40. The United States is the only great nation which has great decentralization in the school system.
41. It is never right to judge rashly.
42. The employers, and no one else, are happy over the new régime.
43. All the countries he visited were not places of rain and thunderstorms.
44. Few understand Shakespeare, except those who have read him over and over.
45. All the phases of mental ability are not measured by intelligence tests.
46. It is never wise to believe all the newspapers say.
47. Nothing but avarice could move him.
48. Everything that we can do cannot better his condition.
49. Our discrimination of sounds and appreciation of beauty of form remain mysteries.
50. Music is not meaningful to all who have excellent hearing.
51. Man like a beast must maintain his life by food and sleep.
52. John Howard and Richard Prince are one and the same man.
53. Where the bee sucks, there suck I.
54. All cannot receive this saying.
55. It is not nice for little girls to kill their baby brothers.
56. Almost any scientist would agree with you.
57. Any fool can drive a Ford.
58. He never loved, who loved not at first sight.
59. The bravest man has yet his fear.
60. Only graduate students are desired as roomers.
61. The Seniors alone voted for the resolution.
62. The Freshmen alone were silent.
63. Juniors alone were playing on the team.
64. How far this state of things was due to the valleys not being yet cut out to near their present depth, it would be raising too intricate geological questions to discuss here.
65. Soft language never fails.
66. Only the good are happy.
67. Seldom does such a knave remain unhung.
68. No woman is worth the trouble it would take to woo her—except one.
69. Two straight lines cannot enclose a space.
70. Two rivers there be, in this far country, that hurry down to the sea.
71. It is never too late to mend.
72. One bad general is better than two good ones.
73. No one is admitted except on business.
74. We smile not only when we are pleased.
75. Every soldier is not a hero.

C. Syllogisms

I. *Simple Syllogisms.*—The following syllogisms are already in logical form. That is to say, each proposition is in logical form and in each syllogism the propositions are arranged in the correct logical order—major premise first, minor premise second and conclusion third.

(*a*) Indicate the major, minor and middle terms with the symbols *P*, *S* and *M* and mark the distribution of each term in both places where it appears in the syllogism. Use abbreviations *dis.* and *undis.*

(*b*) Indicate the mood and the figure of each syllogism.

(*c*) Apply the eight rules above (page 4) to determine whether each syllogism is valid. If it is, so indicate. If it is invalid (violates any of the rules), tell what fallacy or fallacies result.

1. All *B* are *C*, all *B* are *A*, all *A* are *C*.
2. Some polite individuals are honest men, no tax dodgers are honest men, some tax dodgers are not polite individuals.
3. Some *X* are *Y*, no *Z* are *Y*, some *Z* are not *X*.
4. No shadows of celestial bodies are objects which need be dreaded, all eclipses are shadows of celestial bodies, some objects which need be dreaded are eclipses.
5. Some *F* are not *H*, no *F* are *G*, no *G* are *H*.
6. All cows are animals with a cloven hoof, all cows are ruminants, all ruminants are animals with a cloven hoof.
7. No *P* are *Q*, all *R* are *P*, some *R* are *Q*.
8. No event in whose presence the phenomenon (dispersion of clouds) fails to appear, can be the cause of the phenomenon. A rising moon is an event in whose presence the phenomenon may fail to appear. Hence a rising moon is not the cause of the dispersion of clouds.
9. All *D* are *E*, some *F* are *E*, some *F* are *D*.
10. Some morons are not people who should spend their lives driving taxicabs. No morons are persons capable of doing excellent college work. No persons who are capable of doing excellent college work are people who should spend their lives driving taxicabs.
11. No *Z* are *Y*, some *X* are *Y*, some *X* are not *Z*.
12. All hedonists are men who regard pleasure as the supreme good. Some Greek philosophers are men who regard pleasure as the supreme good. Some Greek philosophers are hedonists.
13. No *M* are *P*, some *S* are *M*, some *S* are not *P*.
14. No districts with a seacoast are desert regions. Some New England States are desert regions. Some of the New England states are not districts with a seacoast.

(*a*) What relationships can you discover between the odd and the even numbered syllogisms?

(*b*) What relationship exists between 3 and 11?

II. *Syllogisms Not in Logical Form*

(*a*) Put each of the following syllogisms in logical form, that is, express each proposition in logical form and arrange the propositions in the correct order, giving a name to each.

(*b*) Indicate the major, minor and middle terms and mark the distribution of each term in each syllogism.

(*c*) Indicate the mood and the figure of each syllogism.

(*d*) Determine whether each syllogism is valid or invalid and in the cases where they are invalid, name the fallacy or fallacies.

1. Weak men swear off and strong men quit, therefore men who quit are stronger than men who swear off.
2. "Respectable" men are sent to prison for bribery and all offenses for which respectable people are sent to prison are real offenses, hence bribery must be a real offense.
3. Pithecanthropus was not a man. Pithecanthropus was not an ape. Therefore one animal that was not a man was not an ape.
4. No taxes are easy to collect, for debts that are easy to collect are never paid willingly, and no debts that are paid willingly are taxes.
5. Some Senators favor the World Court because the World Court is similar to the League of Nations and some Senators favor the League of Nations.
6. All people are opposed to war. Some people are opposed to education. Therefore, all who are opposed to war are opposed to education.
7. Since ice cream contains cornstarch and ice cream is made out of milk, everything which is made out of milk contains cornstarch.
8. All lazy people idle away time but no acrobats are lazy and hence no acrobats idle away time.
9. All minors are those who are not allowed to vote, and all aliens are those who are not allowed to vote, therefore all aliens are minors.
10. No nonenforceable edicts are laws and all laws are reached by inductive reasoning, hence nothing that is reached by inductive reasoning is a nonenforceable edict.
11. Since all bachelors may marry and no idiots are bachelors, it follows that no idiots may marry.
12. Since all wise men are beneficial to society and all philanthropists are too, it follows that all philanthropists are wise men.
13. Since all men are actuated by physiological mechanisms inherited from remote ancestors, and many men now live in large cities,

it follows that beings who live in large cities are actuated by dispositions inherited from beings who dwelt in caves.

14. To sow a thought is to reap an action. To reap an action is to reap a habit. Therefore, to reap a habit is to sow a thought.
15. Prudence is a human virtue, and since every human virtue is to be sought with diligence, therefore prudence is to be sought diligently.
16. Because some men are scoffers and all men are not pious, therefore some scoffers are not pious.
17. A worm cannot reason because a worm has no thought and what has no thought cannot reason.
18. Because intense heat is nothing else but a particular kind of painful sensation, and pain cannot exist but in a perceiving being, it follows that no intense heat can really exist in an unperceiving corporeal substance.
19. Sensible things are all immediately perceived, and those things which are immediately perceived are ideas, therefore ideas are sensible things.
20. All Buddhists believe in Nirvana, and they also believe in the law of Karma. Therefore all of those who believe in Nirvana believe in the law of Karma.
21. The example of King Asoka (264-227 B.C.) shows that a man who is a great military genius may also be a lover of peace.
22. No gentleman would consider a suit of chain-armor a fitting present for a bathing beauty. Furthermore, any person who would consider it such ought to make his summer home in a dry and sandy region. Hence, some people who should make their summer home in a dry and sandy region are not gentlemen.
23. The eclipse of a satellite is comparable to the shutting of a shutter. The disappearance of the stars with the coming of dawn is not to be compared to the shutting of a shutter. Therefore, the disappearance of the stars with the coming of dawn is not to be called an eclipse.
24. All Athenians were Greeks. Socrates (an Athenian) had no sense of artistic beauty. Therefore, some people who have possessed a sense of artistic beauty were not Greeks.
25. Many reptiles are poisonous. All poisonous animals should be exterminated. Therefore, some creatures which ought to be allowed to live are not reptiles.
26. It must be borne in mind that some spiritualistic mediums have never been proved to be frauds, also that some mediums have not asked money for their seances. Thus we may say that investigators have demonstrated fraud only in the case of those individuals who have wished to make financial gain from their supposed powers.
27. All Oriental peoples are deeply religious. The Albigensians lead a profoundly religious life. Hence, we may conclude that they were of Oriental stock.
28. Acts committed with hope of reward do not show the moral nature in all its purity. The conduct of all religious devotees is

dictated by hope of reward in heaven. Hence, we must not look to them for clearest examples of moral conduct.

29. Bats, having wings, are birds, since all birds have wings.
30. The Greek studies in conic sections were conducted from purely theoretical interests. These studies, however, have not failed to bear practical fruits in the modern science of astronomy as applied to navigation. This, then, bears witness to the fact that no study, however seemingly abstract and impossible, but finally serves some useful end.
31. Only the lazy are unfortunate. Some well-meaning persons are unfortunate. Therefore, some well-meaning people are lazy.
32. Some of my friends are not persons with an international reputation, for I have friends in this country who are not poets, and some poets living in America, also, have to do without an international reputation.
33. Few sarcastic remarks are entirely true. Sometimes the whole truth had better remain unspoken. Therefore, some remarks which it is better to suppress are the sarcastic ones.
34. Not everything conducive to the public welfare is to be found in pleasure arising from wisdom, for though the pleasures of wisdom are more lasting than those of sense, yet some pleasures less transitory than those of sense are not conducive to the public welfare.
35. Every person who aspires to be truly educated should cultivate his power of deriving pleasure from the contemplation of natural beauty. There are, however, many enrolled in our colleges who do not aspire to become truly educated. Therefore, some people who should cultivate their capacity to enjoy natural beauty are not persons enrolled in our colleges.
36. I know that the man who has just made that out-of-place remark teaches philosophy, for all professors of philosophy are absent-minded, and some absent-minded men make remarks ill befitting the occasion.
37. Some dentists are neither Harvard graduates nor men of high general culture. Hence, some Harvard graduates are not men of wide general culture.
38. Some golfers who wax profane when they miss five putts on a green are poor players. But when I miss five putts on a green I do not swear. So it is clearly apparent that I am a good player.
39. All reptiles shed their skins periodically. Some crawling creatures are not reptiles. Therefore, some crawling creatures do not shed their skins periodically.
40. The old belief that some men who have tasted human flesh can take on the form and habit of wolves by night, is false. Some of the characters in Bram Stoker's *Dracula* were able to take on the form and habit of wolves by night. Hence some of the characters in this book had not tasted of human flesh.
41. Some men are deserving of honor who get none. Some inventors do not receive honor. Hence some inventors deserve honor.

42. Misfortunes never come singly. Some twins are not misfortunes. Therefore, some twins come singly.
43. It is impossible to reduce all elements of consciousness to sensations. Some sensations are aroused by chemical stimuli. Hence there are some elements of consciousness not aroused by chemical stimuli.
44. No good musicians are little boys, for everyone should hear good musicians, while little boys should be seen and not heard.
45. Some total abstainers believe that the Government should not interfere in matters of personal morality. All people who disbelieve in the Government's interfering in matters of personal morality are against prohibition. Hence, some people who do not believe in national prohibition are total abstainers.
46. Some pessimistic systems do not teach life after death. Some Indian philosophies are not pessimistic. Hence, some Indian philosophies teach life after death.
47. The side *B* of the isosceles triangle *M* is not equal to the side *C*. The side *A* of the isosceles triangle *M* is not equal to the side *C*. Therefore, the sides *A* and *B* are equal.
48. Some Christian holidays are pagan feast days renamed. No Christian holidays are days intended for self-mortification. Therefore, some days intended for self-mortification were not originally pagan holidays.
49. The rule that these men who serve to advance civilization should marry is bad, for no person whose family line shows evidence of insanity should marry, and many a man whose family is tainted by insanity has accomplished great and important things in letters, arts, and sciences.
50. No ancient Egyptian ever owned a Ford car. No man who ever owned a Ford car has failed to have engine trouble. Hence, some motorists who have had engine trouble are not ancient Egyptians.
51. Many a true word is spoken in jest. No political campaign platforms are truthful. Hence, some political campaign platforms are no joke.
52. It is false that all Englishmen are civets, for some civets are natives of India and some Englishmen are not.
53. Some swindlers are fools, for no natives of Iowa are either fools or swindlers.
54. No New Englander is a stoic, for all stoics have deprecated the pleasures of the table, but no New Englander ever frowned upon a good dinner.
55. Some cross-word puzzles are not a proper preparation for a morning's work, neither are some movies. Therefore, we must suppose that some movies are cross-word puzzles.
56. Every student who aspires to become a philosopher must read Kant: but Peter Moore has not the least desire of being a philosopher, so he need not read Kant.
57. Some lawyers are republicans. So are some honest men. Hence, some honest men are lawyers.
58. No negro author ever wrote a book praising the Ku Klux Klan.

Some negro authors are not poets. Hence, some poets do not write books praising the Klan.

59. Some who do not weigh what they should not are not persons who do not eat what they ought not. No persons who do not weigh what they ought not are men who do not fail to care what is said of them. Therefore, some who care what is said of them are not persons who eat the proper food.
60. No rich nation, since it perforce must be militaristic, can be a true friend to civilization, for no militaristic nations are such.
61. Some men are happier single than married, but not all people who would get more happiness out of life unmarried are wise enough to remain so. Hence some beings not wise enough to let well enough alone are members of the human race.
62. Aristotle proves that slavery is right, or that some human beings are pieces of property, by showing that every instrument which we make use of for some end is a piece of property, and that some such instruments are human beings.
63. All hermits lose a part of what life has in store for them, for no solitary man can get full value from life, and some solitary men are hermits.
64. Twenty-six of the United States lie east of the Mississippi River. Thirty states voted for Wilson in the campaign of 1916. Therefore some of the states which voted for Wilson in 1916 lie East of the Mississippi.
65. Some problems of modern sociology are not purely economic problems. None of them are to be solved with the accuracy of mathematics. Therefore, some problems in which we should exercise mathematical exactitude are those strictly economic.
66. Nothing that satisfied the postulate of the old-time materialistic systems could be divisible or changeable. Some entities which are highly divisible and changeable are the molecules and atoms of modern science. Hence, molecules and atoms as known and studied by physicists and chemists to-day could not be satisfactory entities for the requirements of the older materialisms.
67. Among our most dreaded insect pests are the chinch-bugs, for any insect pest capable of wiping out our grain supply over large areas is greatly to be dreaded, and the chinch-bugs traveling in companies aggregating many millions, feed upon the stems and leaves of grain, which they devour with extraordinary rapidity.
68. Iodine, being a constituent of sea water, is essential to all animal life which originated in the sea, and since man's remote ancestors lived in the sea, iodine is essential to man.
69. Whales are mammals with an ocean habitat and devil fish are animals with an ocean habitat. Therefore all devil fish are whales.
70. The elephant's trunk is his nose for he uses it for respiratory purposes and the organ which is used for respiratory purposes is the nose.
71. All is not gold that glitters, for the tinsel used for Christmas decorations glitters and we know that tinsel is not gold.

72. All bishops are chessmen; some churchmen are bishops; therefore, some churchmen are chessmen.
73. Sometimes their shots went through the basket and sometimes they didn't, but as the ball has to go through the basket to score in this game, not all their shots counted.
74. The belief of the natives of Borneo that only he is brave who has taken the head of an enemy, is a false belief. Hence, since none of your enemies have lost their heads through your endeavors, you are a brave man.
75. Some who hesitate are lost. No one who is lost can retrieve his fortune. Some who can retrieve their fortunes are not those who hesitate.

III. The Special Rules of the Four Figures and Reduction

(*a*) Construct a syllogism violating each of the following special rules of the four figures, and name the fallacy or fallacies which result. Give the mood of each syllogism and mark the distribution of each term.

1. In the first figure the minor premise must be affirmative.
2. In the first figure the major premise must be universal.
3. In the second figure one premise (and, therefore, the conclusion) must be negative.
4. In the second figure the major premise must be universal.
5. In the third figure the conclusion must be particular.
6. In the third figure the minor premise must be affirmative.
7. In the fourth figure, if either premise be negative, the major premise must be universal.
8. In the fourth figure, if the major premise be affirmative, the minor premise must be universal.
9. In the fourth figure, if the minor premise be affirmative, the conclusion must be particular.

(*b*) Construct a syllogism in each figure to prove that no conclusion can be drawn from two particular premises.

(*c*) Construct a syllogism in each figure to prove that, if one premise is particular, the conclusion must be particular.

(*d*) Construct a syllogism in each figure to prove that the mood *I E O* is invalid.

(*e*) Reduce each of the following syllogisms to the first figure. Note that in some of the examples this can be done by converting one or both premises, whereas in others it is necessary to transpose the premises and convert the conclusion. Indicate the mood and figure before reduction and indicate the mood after reduction.

1. No moonshine is unadulterated.
   All grape juice is unadulterated.
   No grape juice is moonshine.
2. No wildcats are pets.
   All wildcats are ferocious.
   Some ferocious animals are not pets.
3. No stars are near the earth.
   All heavenly bodies that are near the earth are members of the solar system.
   Some members of the solar system are not stars.
4. All eels migrate to the mid-Atlantic to spawn.
   No salmon migrate to the mid-Atlantic to spawn.
   No salmon are eels.
5. All Eskimos live in a cold climate.
   All Eskimos feed on seals.
   Some beings that feed on seals live in a cold climate.
6. All athletes are men of repute among the students.
   No men of repute among the students are effeminate.
   No effeminate students are athletes.

(*f*) Construct a valid syllogism in the second, third, or fourth figure. Indicate its mood and reduce it to the first figure.

D. Irregular Arguments, Hypothetical and Disjunctive Syllogisms, and Dilemmas

I. *Enthymemes.*—Since an enthymeme consists of only two propositions it violates rule one of the syllogism. It is for this reason that it is called an irregular argument. However, the other proposition is implied and can easily be stated. Enthymemes are said to be of the first, second or third order according to whether the major premise, the minor premise or the conclusion is missing.

(*a*) Supply the missing proposition of each of the following enthymemes. Tell which order each is.

(*b*) Indicate the mood and figure.

(*c*) Tell whether valid or invalid and name the fallacy or fallacies of each invalid form.

1. I ought, therefore I can.
2. All men are born good and Napoleon was a man.
3. All who shirk their duty lack moral courage and hence these policemen lack moral courage.
4. Absorption in the study of the occult is harmful for it causes men to neglect their daily duties.
5. They despised knowledge and knowledge destroyed them.

6. Young men should have no depressed thoughts for all bad habits result from depressed thoughts.
7. Religion and science can not collide for they can never meet.
8. I am sure the Lord is remarkably frowning on our trade since it was put in the room of religion.
9. The social teachings of the church had ceased to count, because the church itself had ceased to think.
10. Metaphor is the special work of genius, for the power of making a good metaphor is the power of recognizing likeness. (Aristotle.)
11. Tchekov wrote to Gorky: "You are an artist. You feel superbly. You are plastic. . . . Your writing is real writing."
12. The world we live in is a new world. Nobody ever lived in such a world before. It is a bigger world because there are more people in it. It is a smaller world because one can get around it quicker. It is a more complex world because of the many new forces that have entered into it. It is a simpler world to understand, for it has been more thoroughly studied and classified. Edwin E. Slosson, *Chats on Science*, p. 5 (The Century Co.).
13. Since all Chinamen are Confucianists, it follows that no Chinamen are Taoists.
14. All that lives must die, passing through nature to eternity, said Shakespeare, and hence he must have believed in immortality.
15. A lawyer who was cross-examining an Irishman on the witness stand said, "You are lying, I can see it in your face." The Irishman answered, "My face must be mighty bright and shining indeed since it can reflect like that."
16. All who would tolerate war are anti-Christian and many college professors are tolerant toward war.
17. None but pacificists are Christians, and therefore many Catholic priests and Protestant pastors are not Christians.
18. The fact that philosophers differ among themselves as to the ultimate nature of reality, proves that metaphysics is a worthless subject and should not be studied.
19. Men can make a better world because the present social order is a sorry state of affairs.
20. Since all religions are permeated with superstitions, it follows that no religions are true or worthy of man's acceptation.

II. *Sorites.*—A chain of reasoning consists of a series of syllogisms in which one proves the premises of another. The *sorites* is the most common form of a chain of reasoning. It is always in the first figure, only the last conclusion is expressed and the suppressed conclusions serve as premises of the intermediate syllogisms. There are two forms—the Aristotelian, which states the minor premise first, and the Goclenian, which states the major premise first. Both premises of the first syllogism are given. Hence a sorites will break up

into as many syllogisms as there are premises, less one. In the Aristotelian form only the first premise may be particular and only the last premise may be negative. In the Goclenian only the first may be negative and only the last may be particular.

(*a*) Break up the following sorites into syllogisms. Draw the conclusion from the first two premises and then use it with the next premise to form the second syllogism, and so on until you reach the conclusion given in the sorites. Indicate each fallacy you discover.

1. Religious belief produces optimism.
   Optimism produces courageous endeavor.
   Courageous endeavor produces a superior mastery over circumstances.
   Therefore, religious belief produces a superior mastery over circumstances.
2. He who reserves judgment on what seems doubtful is one who seldom falls into error.
   He who is cautious reserves judgment on what seems doubtful.
   He who seldom has to repent of his actions is cautious.
   Therefore he who seldom has to repent of his actions is one who seldom falls into error.
3. Science gives man a greater control over nature.
   A greater control over nature augments human wealth.
   An increase in human wealth leads to an increase in culture.
   An increase in culture enriches the content of every individual's life.
   Therefore, science enriches the content of every individual's life.
4. All who are truly benevolent are free from care.
   All who are truly wise are truly benevolent.
   All who are free from delusions are truly wise.
   All who are truly brave are free from delusions.
   All who are free from fear are truly brave.
   Therefore, all who are free from fear are free from care.
5. All politicians are tactful.
   Some tactful people are courteous.
   Some courteous people are good conversationalists.
   Some good conversationalists are educated.
   Some educated people are politicians.
6. No Buddhists are Eskimos.
   Some natives of Ceylon are Buddhists.
   Some black people are natives of Ceylon.
   Some black people are not Eskimos.
7. No American Indians are Mohammedans.
   All Mohammedans are natives of the old world.
   All natives of the old world are non-pacificists.
   No non-pacifists are American Indians.

8. All white elephants are sacred in India.
No opossums are white elephants.
All North American animals which carry their young in a pouch are opossums.
No North American animals which carry their young in a pouch are sacred in India.

9. Sun spots cause the weather.
The weather causes the crops.
The crops cause the economic conditions.
The economic conditions cause the migrations of peoples.
The migrations of peoples cause racial ill-will.
Racial ill-will causes race-hatred.
Race-hatred causes war.
Therefore, the sun spots cause war.

10. All who have no prejudice against manual labor are relieved from the terror of losing caste.
All who are relieved from the terror of losing caste live with confidence.
All who live with confidence live with enhanced vitality.
All who live with enhanced vitality live lives of vehement activity.
All who live lives of vehement activity make lasting contributions to human welfare.
Therefore, all who have no prejudice against manual labor make lasting contributions to human welfare.

11. Wood, stones, fire, water, flesh, iron, and the like things, which I name and discourse of, are things that I know. And I should not have known them but that I perceived them by my senses; and things perceived by the senses are immediately perceived; and things immediately perceived are ideas; and ideas cannot exist without the mind; and therefore the existence of wood, stones, fire, water, flesh, iron, and the like things consists in being perceived. (Adapted from Bishop Berkeley's *Three Dialogues*, Open Court Edition, p. 90.)

III. *A Fortiori and Other Irregular Arguments.*—There are a number of forms of reasoning which are irregular in the sense that they have four or more terms but which may, nevertheless, be valid. They operate with various relations such as *space, time* and *quantitative* relations. The *a fortiori* argument is a common type of reasoning of this general form. Here is an example. When a single observer sees a table differently from different points of view, "it is easy to see that two, or more, observers looking at the table from different angles and each with his own quality of vision, will differ even more in what they perceive" (Hoernlé). Such an argu-

ment may be expressed in the form of three propositions by stating the assumption on which it rests as one premise, just as is done with the enthymeme type of reasoning. Thus the example just given would take the form:

It is admittedly easier for a single observer to see the table as a single object than it is for two or more observers.

But one observer sees it differently from different positions.

Therefore, two or more observers will see it differently according to the quality of their vision and their respective positions.

(*a*) Distinguish the *a fortiori* arguments in the following list from those dealing with spatial or temporal or quantitative relations.

(*b*) State each *a fortiori* argument in the form of three propositions, making the implicit assumption one of the premises.

(*c*) List the different logical terms there are in each example.

(*d*) State whether each argument is valid. If invalid explain why.

1. "Chi Lu inquired concerning men's duty to spirits. Confucius replied: 'Before we are able to do our duty by the living, how can we do it by the spirits of the dead?'"
2. "Chi Lu went on to inquire about death. Confucius replied: 'Before we know what life is, how can we know what death is?'"
3. Mexico is north of Panama.
   Panama is north of Peru.
   Therefore, Mexico is north of Peru.
4. Since the New York American League team defeated the St. Louis National League team in the 1926 World Series, and since the St. Louis National League team defeated the Cincinnati National League team, it follows that the New York Americans could have defeated Cincinnati.
5. It is an altogether incredible supposition that the Polynesian sailors who searched many thousands of miles in the Pacific with such thoroughness as not to miss even the minutest islets were not repeatedly landing on the shores of America for ten centuries and more. How could the people who found Hawaii, Easter Island and New Zealand have failed to discover the vast continent stretching from pole to pole?
6. The Rocky Mountains are west of the Mississippi River.
   The Mississippi River is west of the Appalachian Mountains.
   Therefore the Rocky Mountains are west of the Appalachian Mountains.
7. If, as Professor Bliss Perry says, no man can understand America with his brain, how can he with the same instrument understand the Deity? (S. Parkes Cadman.)

8. Yale has a stronger football team than Harvard.
Harvard has a stronger team than Dartmouth.
Therefore Yale has a stronger team than Dartmouth.
9. "If our printed books, after the successive revisions of author and printer's reader, are still but imperfect reproductions, it is only to be expected that ancient documents, copied and recopied as they have been for centuries with very little care, and exposed at every fresh transcription to new risk of alteration, should have reached us full of inaccuracies." (Langlois and Seignobos, *Introduction to the Study of History,* p. 73.)
10. Latvia is a younger nation than the United States.
The United States is a younger nation than England.
Therefore, Latvia is a younger nation than England.
11. Spitzbergen is east of the North Pole.
The North Pole is east of Alaska.
Therefore, Spitzbergen is east of Alaska.
12. When we enter the subway there occurs some psychological change which exaggerates the impressions from the sense of hearing and makes us imagine the noise to be much louder than it is. But if a mental attitude, largely unconscious, can affect so profoundly a simple thing like our judgment of subway noise, it is no wonder that preconceptions and the mental temper of the times are so powerful in more complicated activities of men. (*Forum,* Vol. LXXI, illustrated section, p. xxxv.)
13. It ought not to be said of us (preachers) that while science steadily reclaims large tracts of territory from the unknown and the debatable and places them at man's service, theology retreats behind its venerable breastworks and there digs in. If organized research can constantly bring within the sphere of law beneficial things formerly ascribed to the supernatural, surely ministers of the Gospel must not become laggards in a field presumably their own. (S. Parkes Cadman, *Imagination and Religion,* The Macmillan Co., p. 57.)
14. Mt. Everest is higher than Mt. Blanc.
Mt. Blanc is higher than Mt. Washington.
Therefore, Mt. Everest is higher than Mt. Washington.
15. If Belgium can save millions by cutting down the amount of wheat eaten, how many billions can France save by cutting down eight-course meals to three, and by forbidding two kinds of meat and fish at the same meal? If the American citizen is satisfied to get one heavy meal a day, with meat or fish, why should he pay the bills of the French citizen who demands two heavy meals and twice as much at each meal? When M. Poincaré answers these questions he will have saved the franc. (*Boston Transcript.*)
16. It has always been an axiom that a man's life is of greater consequence than an animal's life.
When Doctor Grenfell was afloat on an ice pan, and killed three of his faithful dogs that he might get their skins to keep himself

from freezing, the world applauded him for the brave, resourceful man he is. It was considered better that they should suffer and die than that he should suffer and die.

Yet I know that Doctor Grenfell will not misunderstand me when I say that the killing of those dogs was selfishness personified when compared with the work of the vivisectors. He killed three dogs, his personal friends, to save one life—his own. The vivisectors take no such toll as that. For every animal they cause to suffer and die, they save unnumbered human beings from suffering and death. As I have said, the question is one of proportion. The greater the cause, the greater the sacrifice which it justifies. (*Boston Transcript.*)

17. The release of the E. I. du Pont de Nemours & Co. semi-annual report directs attention to one of the great beneficiaries of the General Motors prosperity, notwithstanding glowing reports of the Durant achievements. Du Pont earned $14.51 a share in the first six months of 1926, against $6.70 a share in the first half of 1925. But roughly for every share of du Pont outstanding, the company owns a share of General Motors, and as General Motors paid $8.50 a share in dividends the first half-year, du Pont's profits from its own operations are presumably about $6 a share. As General Motors earned $17.33 a share the first half-year, it is evident that du Pont's equity in earnings undistributed is much more than the $14.51 a share reported. It would be closer to the facts to say that du Pont's earnings for the first half-year were about $23.34 a share. (*Idem.*)
18. No man of science has a closer opportunity nor a more commanding impulse to question the concept of a beneficent controlling principle than the cancer expert. Here is a place where creation seems to have gone dead wrong—where a hideous mischance is supreme over the principle of life. At the root of cancer lies what seems to us to be creative blindness resulting in false cell development. If the cancer expert's faith in God is not shaken by the condition, as, for example, Dr. Adami's was not, then the hope of none other need waver. (*Idem.*)
19. The *Divine Comedy* was written before *Paradise Lost.*
Homer's *Iliad* was written before the *Divine Comedy.*
Therefore, Homer's *Iliad* was written before *Paradise Lost.*
20. If one succeeds in showing "that the concrete triple event, of ability combined with zeal and with capacity for hard labor, is inherited, much more will there be justification for believing that any one of its three elements, whether it be ability, or zeal, or capacity for labor, is similarly a gift of inheritance." (Francis Galton in *Hereditary Genius,* p. 38.)
21. I then will ask you, if a man, in worshipping . . . sacrifices a sheep, and so does well, wherefore not his child . . . and so do better? Surely . . . there is no merit in killing a sheep! (Fo-pen-hing-tsih-king. *Buddhist Sayings.*)

IV. *Hypothetical and Disjunctive Syllogisms*

(*a*) Tell which of the various forms of hypothetical and disjunctive syllogisms each of the following is.

(*b*) State whether each example is valid or invalid. Name the fallacy of the invalid forms. A disjunctive syllogism is invalid if the alternatives are not exhaustive and mutually exclusive.

(*c*) Reduce each hypothetical syllogism to categorical form, give the mood and figure, and name the fallacy in case there is one.

1. Human civilization could only have arisen either by independent invention or by diffusion. It did not arise by independent invention and therefore it arose by diffusion.
2. If a reflection in the water is not an example of vertical symmetry, then it must be an example of horizontal symmetry. It is an example of horizontal symmetry and therefore it is not an example of vertical symmetry.
3. Either the fundamentalists are right or the Bible is not infallible on matters of science. But the fundamentalists are certainly not right. Therefore the Bible is not infallible on matters of science.
4. If the price of farm products rise, then the value of farm lands will not decrease. But the price of farm products will not rise, therefore the value of farm lands will decrease.
5. If Ford is to sell more cars to his employees then he must allow them more leisure. But he cannot allow them more leisure and consequently he cannot sell them more cars.
6. Either the Democratic or the Republican Party will carry Ohio in the coming elections. But straw-votes show that the Republican Party cannot carry Ohio, and hence the Democratic Party will certainly carry it.
7. If trees require cold weather as a stimulus to growth then trees not periodically subjected to cold will not grow. But trees do require cold weather as a stimulus to growth and therefore those trees not periodically subjected to cold will not grow.
8. Either the weakest can kill the strongest or the strongest can kill the weakest. But according to Thomas Hobbes the weakest can kill the strongest and therefore the strongest cannot kill the weakest.
9. If astronomers prove that Mars is inhabited some inventor will discover a way of communicating with the inhabitants. But it is inconceivable that a way can be found to communicate with lower forms of life, and therefore astronomers can never prove that Mars is inhabited.
10. A man with acute appendicitis must either undergo an operation or die. This sufferer has undergone an operation, and therefore he will not die.
11. If cancer is a bacterial disease then it is communicable. But cancer is communicable and therefore it is a bacterial disease.
12. Apple trees which are not sprayed either produce worm-infested

fruit or they are barren. These unsprayed apple trees are not barren and therefore the fruit is worm-infested.

13. If a poor man marries a wealthy woman he may expect to cater to her whims, but this poor man has married a wealthy woman and therefore he must expect to cater to her whims.
14. If college students do not take their work seriously, the colleges will gradually lose prestige, but college students are taking their work seriously and therefore the colleges will not lose prestige.
15. If hurricanes do not destroy Miami, Florida, she will continue to be a boom city. But she will not continue to be a boom city and therefore hurricanes will destroy her.
16. Either he will make Phi Beta Kappa or he will not make Phi Beta Kappa. He will not make Phi Beta Kappa and therefore he will make Phi Beta Kappa.
17. The following is a hypothetical sorites. Break it up into pure hypothetical syllogisms. "If terms are not correctly defined, words will not harmonize with things. If words do not harmonize with things, public business will remain undone. If public business remains undone, order and harmony will not flourish. If order and harmony do not flourish, law and justice will not attain their ends. If law and justice do not attain their ends, the people will be unable to move hand or foot." (Confucius.)
The conclusion would be: If terms are not correctly defined, the people will be unable to move hand or foot.
18. The following is a chain of reasoning, partly hypothetical and partly categorical. Break it up into syllogisms. "If we cannot be sure of the independent existence of objects, we cannot be sure of the independent existence of other people's bodies, still less of other people's minds, since we have no grounds for believing in their minds except such as are derived from observing their bodies. Thus if we cannot be sure of the independent existence of objects, we shall be left alone in a desert—it may be that the whole outer world is nothing but a dream, and that we alone exist." (Bertrand Russell, *Problems of Philosophy*, pp. 26 *f.*)
19. The following is a hypothetical and disjunctive chain of reasoning. Break it up into syllogisms. Only two things are possible; either you are of draft age, or you are not of draft age. If you are not of draft age there is no need to worry. If you are of draft age only two things are possible; either you are called, or you are not called; if you are not called there is no need to worry. If you are called only two things are possible; either you are sent to camp, or you are not sent to camp; if you are not sent to camp there is no need to worry. If you are sent to camp only two things are possible; either you stay in this country, or you do not stay in this country; if you stay in this country there is no need to worry. If you do not stay in this country, only two things are possible; either you are sent to the front, or you are not sent to the front; if you are not sent to the front

there is no need to worry. If you are sent to the front, only two things are possible; either you see action or you do not see action; if you do not see action there is no need to worry. If you see action only two things are possible; either you are wounded, or you are not wounded; if you are not wounded there is no need to worry. If you are wounded, only two things are possible; either you are wounded seriously, or you are not wounded seriously; if you are not wounded seriously there is no need to worry. If you are wounded seriously, only two things are possible; either you die, or you do not die. If you do not die there is no need to worry. If you do die you can't worry.

(*a*) Use the following hypothetical and disjunctive propositions as the major premises of syllogisms and state a minor and a conclusion to complete a syllogism. Note that in some of the examples the major must be restated to get it into correct logical form.

(*b*) Tell which form each is and name the fallacy in case there is any.

1. If any two mental states be called up together or in succession, with due frequency and vividness, the subsequent production of the one of them will suffice to call up the other.
2. Coördinate activity always testifies either to inborn stored-up power or to acquired stored-up power.
3. If the theory of the conservation of energy is true then the human will can not create new energy.
4. If a good rule is better than a bad one, then any rule is better than none.
5. If the national character of a people can be altered, then this can be only a slow and gradual process.
6. "What our shadows seem, forsooth, we will ourselves be. Do I look like that? You think me that; then I am that."
7. Either savages are bound by custom or most anthropologists are wrong.
8. If you speak two languages, you are a rascal.
9. If savage races cannot withstand the diseases of civilization then civilized nations will eventually destroy them.
10. Carlyle said that the ultimate question between every two human beings is "Can I kill thee, or canst thou kill me?"
11. All the authorities agree that when a revolution begins it is bound to work itself out.
12. If a heavenly body is a planet, it will appear as a disc.
13. Either Sirius appears as a disc or it appears as a point of light.
14. If an X-ray can be refracted, it will show the colors of the visible spectrum.
15. If positivism is the true philosophy, Hegelian philosophy is as antiquated a branch of knowledge as astrology or alchemy.

V. *The Dilemma*

(*a*) Each of the following states a dilemmatic situation. Construct at least one dilemma out of each, and more than one if you can. Tell which form of dilemma each example is.

(*b*) Tell at least one way in which each dilemma which you think is invalid might be met and tell why you think those you take to be valid are valid.

1. "Everything that goes to make up the highest pride of the West is due to the fact that it has desired the impossible; the Confucian only wants the possible. Here one must choose one of two alternatives; either we desire the superman—then we can have no consideration for the masses; . . . or else we want to lead the masses as they are to perfection and then one renounces the higher types." (Count H. Keyserling, *Travel Diary of a Philosopher,* Harcourt, Brace & Co., Vol. II, pp. 118 *f.*)
2. "Scientists think that critics of their method are simply beating the air. In fact, if the logician decides that scientific procedure is irrational, he must be wrong; if he decides it is rational he is wasting his time discovering what every one knows already. His position is as uncomfortable as that of the medieval philosopher discussing the dogmas of the Church." (A. D. Ritchie, *Mind,* N. S., Vol. XXXV, p. 301.)

   Note that two dilemmas are here implied—one in which the logician and one in which the medieval philosopher is placed. State each.
3. The advocates of the principle "China for the Chinese" argue that the United States can no longer maintain the Open Door Policy of John Hay without either antagonizing Japan or making a defensive alliance with European nations, both of which it would be a fatal mistake to do.
4. Certain social workers seem to think that laboring people can only profit by higher wages by the cost of living remaining the same or decreasing; and, on the other hand, that they can only hold their positions so long as foreign immigration is rigorously restricted. But it looks as if any rise in wages would either be accompanied by higher living costs or by an influx of foreign labor.
5. The advocates of the principle of American isolation argue that the entrance of the United States into the League of Nations will inevitably involve a great expense to our tax-payers and an entanglement in European diplomacy.
6. It seems that America is bound to be the loser in the settlement of the war debts for she will lose the money due, if the debts are cancelled, and she will lose a great deal of the principal and interest, if the debt agreements are carried out to the letter.
7. In Bishop Berkeley's *Three Dialogues between Hylas and Philonous,* p. 61 (Open Court Edition), Hylas advances the theory that

ideas are occasioned by impressions in the brain, and Philonous answers him as follows: "Besides spirits, all that we know or conceive are our own ideas. When, therefore, you say all ideas are occasioned by impressions in the brain, do you conceive this brain or not? If you do, then you talk of ideas imprinted in an idea causing that same idea, which is absurd. If you do not conceive it, you talk unintelligibly, instead of forming a reasonable hypothesis."

8. We are forced to choose between two alternatives, either the assumption that the world of personality and the world of nature are two worlds tenuously connected but for all practical purposes divided, or that the world of personality is an effervescence in the natural world which has no permanence beyond the biological processes which generate it. That is, we must believe either that God is the ideal who intrigues the heart of man without being practically related to the world in which man lives, or that the human soul is orphaned in the universe. (*Christian Century*, Vol. XLIII, p. 1192.)
9. Many historians are confronted with a dilemma, according to Langlois and Seignobos' *Introduction to the Study of History*, p. 33. "Either they must work on a supply of documents which is in all probability incomplete, or they must spend themselves in unlimited researches, often fruitless, the results of which seldom appear worth the time they have cost."
10. In the opening chapter of his *Pragmatism*, William James recommends this new philosophy on the ground that there is a dilemma in philosophy. If a man is a lover of facts and accepts the empirical philosophy, his religious needs will not be satisfied by that philosophy, and if he is a lover of principles and accepts the philosophy of rationalism, he must be content with a philosophy hostile to science.
11. It would seem that religious fanaticism such as was exhibited at the Scopes Trial at Dayton, Tenn., can only be held in check, either by restraining agnostic thinkers like Mr. Darrow from freely expressing their views, or by a wide dissemination among the rank and file of religious people of the new ideas about the Bible.
12. In the *Dial*, Vol. LXXXI, p. 186, Bertrand Russell argues: "If we emphasize the fact that our belief in causality and induction is irrational, we must infer that we do not know science to be true, and that it may at any moment cease to give us the control over the environment for the sake of which we like it. . . . If, on the other hand, we admit the claims of scientific method, we cannot avoid the conclusion that causality and induction are applicable to human volitions as much as to anything else."
13. The water and coal crisis aboard the *Noma* had reached the critical point where something must be done and that without delay. The situation was complicated by the facts that if we burned coal in order to cruise about and search for water, we

should not have enough fuel left to reach Panama, even if we found the longed-for fluid; if we did not burn coal in such a quest, we should expire of thirst before we reached Panama anyway." (William Beebe, *Galápagos or World's End,* p. 196.)

14. The phonograph manufacturers are confronted with a serious situation. For either the radio will take the place of phonographs or the phonograph manufacturers will have to make a combination radio and phonograph machine, and in either case the manufacturers will lose considerable money.
15. If a college student is to get the respect of his teachers, he must study consistently every day; but if he is to receive the plaudits of his fraternity brothers, he must always be loyal to the chapter. But these two ideals conflict so that he cannot do both.

E. *Fallacies*

(*a*) In each example point out precisely where you think the fallacy lies.

(*b*) Give a name to the fallacy you find in each example.

1. We come to college to improve our faculties and, since our faculties are our teachers, we come to college to improve our teachers.
2. The World's Series in baseball must have been honestly conducted, for President Coolidge, who saw every game played in Washington, D. C., said that he did not detect a single sign of dishonesty.
3. If you buy a ton of coal in the United States for ten dollars this country will have the ton of coal and the ten dollars, but if you buy a ton of coal for ten dollars from a dealer living in Great Britain, this country gets the coal but England gets the ten dollars.
4. A man who was out walking met another man walking, and exclaimed: "You like to walk alone, I like to walk alone and some day we must do it together."
5. We must believe what the prophet of the Mormons, Joseph Smith, says, for the Book of Mormon states that Smith is a true prophet, and whatever the Book of Mormon says comes directly from God, since Smith said that he received the book directly from an angel messenger from heaven.
6. If a man contend that he has defined all his terms and proved all his propositions, then he has either performed a logical miracle or he is an ass, and, as everybody knows, logical miracles are impossible.
7. Many a jury has failed to reach a verdict because of the obdurate attitude of one or two men. Yet the expedient of reducing the number of jurors to eleven or ten would promise no better results. A jury of nine would be entirely capable of reaching an eight-to-one deadlock. (*Washington Star.*)

8. Sharks sometimes rubbed their backs against the boat, mostly under seven feet.
9. "The Inquisition must have been justified and beneficial, if whole peoples invoked and defended it, if men of the loftiest souls founded and created it severally and impartially, and its very adversaries applied it on their own account, pyre answering to pyre." (B. Croce, *Philosophy of the Practical*, p. 71.)
10. There are 16,000 lectures and sermons delivered in metropolitan New York each week. If they average twenty-five minutes in length, one person, if he heard all, would require more than forty years of actual time each twelve months. Yet there were 387 murders in New York in 1924. More money is stolen in New York each year than it costs to carry on even a Hylan administration. Isn't there some better method to influence public morals than sermons?
11. Why is it that women are more devoted to religion than are men?
12. Why is it that a young man earnestly desirous of attaining a more distinctly religious life meets with so much opposition from his associates?
13. I saw a man last summer who boasted that he had "doped" the winners of the World's Series baseball games correctly for the last twenty years. At first I thought that he was boasting but consideration showed that on the basis of probability there should be not one, but nine or ten such persons somewhere in the United States. There are, I should say, ten million people in this country who try to pick the series winner each year. On the average half of them should be right—five million. Next year half of this five million should again be true prophets, 2,500,000. This would mean a million and a quarter guessing correctly for three years straight, six hundred thousand or so for four years straight. Continuing the division there should be nine or ten individuals having a twenty-year run of luck.
14. Barbers have been cutting hair for generations. Your barber is an expert.
15. Whatever you say passes through your mouth. You say a wagon. Therefore, a wagon passes through your mouth.
16. A resolution favoring the enforcement of the Volstead Act has been passed by the National Federation of Women's Clubs. As there are two million women in these clubs, it means that two million women have endorsed it.
17. It is impossible to grade accurately to within one point in a hundred. Therefore, whenever a student receives a 92 in a course it should be changed to a 93.
18. Pat was trying to induce Mike to take a drink of moonshine. "Didn't Paul write to Timothy," he asked, "telling him to take a little wine for his stomach's sake?" Mike answered, "In the first place my name's not Timothy, in the second place that is not wine, and in the third place there is nothing the matter with my stomach."
19. Morrison's experiments tending to show that dogs have a very

weak color sense should be rejected, for he was named co-respondent in a recent divorce suit.

20. There should be no law requiring motor vehicles to pass one another on a stated side, for some countries (such as the United States) say that one should turn to the right, others (such as England) say that one should turn to the left.

21. All finite beings are contingent; that is, their nature is not such that they always must exist, but their continued existence depends on circumstances. For example, there is nothing about Bascom Hall that assures us that it will exist forever, but rather its continued existence through a very long period will depend upon constant repairs and protection from fire, etc. But since time is limitless all things which are possible must occur therein. But, as we have just shown, all finite things are contingent, that is, it is possible that they perish. But since all possibilities must be realized, this too must be realized, and hence there will be a time when all finite things shall cease to exist, and the universe of finite things shall be destroyed.

22. America is a Christian nation. Christians put their faith in the way of life which Christ has shown us, and not in political machinery. Let us not, therefore, join the World Court. Let us rather remain in the Hague Tribunal, which past experience shows us works well.

23. Smith has seen a pair of dice cast 34 times without producing double sixes. As he knows that double sixes should appear once in thirty-six times, he concludes that he can afford to bet even money that they will appear next time. What ratio should he bet, and why?

24. Quoting from J. B. Watson, *Behavior,* p. 310, "We do not admit (reasoning) as a genuine type of human behavior except as a special form of language habit," Graham Wallas comments as follows: "Dr. J. B. Watson, it is true, and his followers say that any thought of a chess player which does not cause his hand to move towards the pieces does cause his internal or external speech organs to move—or rather actually consists of such movements, though they may be both invisible and inaudible. But Dr. Watson's only proof that this belief is true is apparently the circular argument that if it were not true the extreme behaviorist dogma would be unsound." (*The Art of Thought,* p. 43.)

Explain why such an argument is circular.

25. "Some people are especially rigid about loose talk, some about drink, some about public worship (for or against), some about giving no pain to animals, some about literal truth-telling, and so on. But if you go so far as to make any one of these 'precisions' an absolute and unbending rule, doctrinairism is at hand, and madness is in sight."

"In the background of this error there is probably a common prejudice, which, logically stated, is the belief that there is truth which is quite true, and error which is quite false. Then, when

you have admitted a principle, say, pain is a bad thing, you are chained by it hand and foot. If pain is a bad thing, it is wrong to inflict pain, and all the king's horses and all the king's men cannot make it right. So with the evil of lying or the use of force, the excellence of gentleness, and so forth." (Bernard Bosanquet, *Some Suggestions in Ethics,* The Macmillan Co., pp. 252 *f.*) What is the fallacy pointed out by Bosanquet? Give reason for your answer.

26. Referring to certain evils in modern society as "inevitable and perhaps wholesome," Bosanquet remarks that for so doing he may be called a "Hegelian or a relativist or an optimist, and perhaps worse names than any of these." (*Idem,* p. 260.) Supposing those who do not agree with him were to call him such and even worse names, what fallacy would they commit? Explain why.
27. Since a Chicago man, earning a small salary, forgot who he was and, when he remembered, three years later, had made $30,000 in a business venture, amnesia is surely a helpful disease.
28. A newspaper reporter asked the following question: "When Henry Ford says that people are buying too many things on installments, is the well-known flivver to be included among the too many?" What fallacy did the reporter commit?
29. "An Esquimo whose tribe had been unsuccessful in hunting and were on the verge of starvation started out on a hunt, gnawing at the hambone of a dog. He was immediately successful in capturing a seal. Thereafter he always took along a hambone of a dog when he went hunting." (W. K. Wright, *Student's Philosophy of Religion,* p. 53.)
30. An attempt to burglarize E. N. Parker's store was frustrated when the would-be burglar struck a dog with a missile that barked and scared him away. (*Boston Transcript.*)
31. "Necessity knows no law." Nor do bootleggers—thus we see by logic the bootlegger is, is he not, a necessity? (*Idem.*)
32. The following strange communication has reached us from the publicity department of the publishing house mentioned: "This business of Miss and Mr. which Joel Rogers of the Century Company and Robertus Love, a Putnam author, have started between them, seems to be reaping an enormous harvest of correspondence in the Putnam office anyway. Editors, booksellers, and various publicity people are getting most self-conscious and write inquiring gender most carefully. At least one has asserted definitely that he knows Blair Niles' wife, so for the information of the world at large be it noted that it's Mrs. Niles who is Blair and writes the travel biographies." We have read this forward and backward several times, but so slow-working is our brain that we are unable to discover its meaning. (*Idem.*)
33. Professor Fisher says the dollar is now worth only sixty-eight pre-war cents. Those who took care of pre-war cents under the impression that the dollar would take care of itself may now question the truth of the familiar adage. (*Idem.*)

34. England has her gloomy dean. Dr. Alexander Meiklejohn, who describes democracy as "a delusion gospel," may be said to qualify as America's gloomy pedagogue. (*Idem.*)

35. There are few men living who are more deeply learned in the physical sciences than the late Dr. John George Adami, who, in addition to being vice-chancellor of the University of Liverpool and a great all around man of science, was incidentally a cancer expert. Dr. Adami was well known to American savants through his long connection with McGill University and his membership in American and Canadian scientific societies. Lately he died in England, and he left behind him a paper in which he declares, not that he is able to affirm the existence of God as a "scientific fact," but that he has been able to accept it as an eternal verity. (*Idem.*)

If a preacher were to use this as an argument to prove the reality of God, what fallacy would he commit?

36. Crime cost the United States three billion dollars in 1924. In the same year the Y. M. C. A.'s in the United States and Canada, their national, State and training agencies and their services in thirty countries cost only $51,914,400. "Fill the Y. M. C. A. and keep the prisons empty," recently wrote the noted English journalist and author, P. W. Wilson. The cost of crime in a single year in the United States would pay, on the current basis, all the expenses of all the Y. M. C. A.'s in the United States and Canada for sixty-two years.

37. The chief argument advanced by Mr. Ford in behalf of the five-day week is that it will make the whole population richer if the people work only five days a week, because in that case they will have a whole day in which to spend their money. The fewer the hours of labor, the more hours of spending; and everybody will profit by the consequent increased sale of goods and more rapid and general turnover of money. (*Boston Transcript.*)

38. The current theory is that labor may produce just as much in shorter hours as in longer, if not more. When working hours were reduced from fourteen hours to twelve, and then from twelve to ten, there was actually increased production. It is by no means demonstrated, however, that the same was true of the reduction from ten hours to eight. The theory seems to break down when it is carried too far. And so, perhaps, may the theory that the more time everybody puts in spending his money the richer everybody will be. (*Idem.*)

39. Ernst Mach tells of two criticisms which were made when he announced his discovery of the sense of equilibrium. One was: "If a sixth sense existed it could not fail to have been discovered thousands of years ago." He answered: "Indeed, there was a time then when only seven planets could have existed!"

40. Mach and others proved that the sense organ of equilibrium is the labyrinth of the ear. The second criticism was: "Animals exist which have no labyrinth, but which can yet orient themselves, and consequently the labyrinth has nothing to do with

orientation (equilibrium)." Mach answered: "We do not walk forsooth with our legs, because snakes propel themselves without them!" (E. Mach, *Popular Scientific Lectures,* Open Court Publishing Co., p. 297.)

41. According to Charles Dudley Warner, orthodox Mohammedans believe that Mohammed will sit astride a column overhanging the valley of Jehosaphat on the last or judgment day. "A line finer than a hair and sharper than a razor will reach from it to the tower on the Mount of Olives, stretching over the valley of the dead. This is the line Es-Serat. Mohammed will superintend the passage over it. For in that day all who ever lived, risen to judgment, must walk this razor-line; the good will cross in safety; the bad will fall into hell, that is into Gehenna, this blasted gulf and side-hill below, thickly sown with departed Jews. It is in view of this perilous passage that the orthodox Mohammedan, every day when he is washing his feet, prays: 'O Lord, wilt Thou make my feet not to slip on Es-Serat, on that day when feet shall slip?'"

42. This must be a just and intelligent decision which the jury has reached, since every man on the panel from which the jury was selected is a property holder and a responsible citizen.

43. The evil will appear as almost nothing in comparison with the good, if we once consider the real magnitude of the City of God. . . . Our earth is only one among the six principal satellites of our sun. As all the fixed stars are suns, one sees how small a place among visible things our earth takes up, since it is only a satellite of one among them. Now all these suns *may* be inhabited by none but happy creatures; and nothing obliges us to believe that the number of damned persons is very great; for *a very few instances and samples suffice for the utility which good draws from evil.* Moreover, since there is no reason to suppose that there are stars everywhere, may there not be a great space beyond the region of the stars? And this immense space, surrounding all this region, . . . may be replete with happiness and glory. . . . Thus the part of the Universe which we know, being almost lost in nothingness compared with that which is unknown to us, but which we are yet obliged to admit; and all the evils that we know lying in this almost-nothing; it follows that the evils may be almost-nothing in comparison with the goods that the Universe contains. (LEIBNIZ, as quoted by William James in *Pragmatism,* pp. 25 *f.* James's italics.)

44. Hoernlé writes: "Here is a characteristic passage illustrating the nature of Berkeley's reasoning. 'What are houses, mountains, rivers, and in a word all sensible objects, but the things we perceive by sense? and what do we perceive besides our own ideas or sensations? and is it not plainly repugnant that any one of these, or any combination of them, should exist unperceived?' This argument is, certainly, highly questionable. Professor R. B. Perry, with his genius for inventing technical labels, calls it the 'fallacy of initial predication.' We begin by perceiving, say, a

color and call it an 'idea' (*i.e.*, an 'object which we perceive.' And then, having so labelled it, we go on to say that it would be a contradiction for an object of perception ever to exist unperceived. But, really, this is arguing from the fact that we have called the color an object of perception to the conclusion that the color can never exist unperceived. The illegitimacy of the inference is disguised by Berkeley's introduction of an intermediate step in the term 'idea.'" (*Idealism,* p. 94.)

45. Since the 1926 St. Louis National League Baseball Team was by far the best team that city has had since it has been in the National League, it follows that every member on the team was an exceptionally good individual player.
46. Professor E. W. Hopkins makes the following criticism of Professor McKenzie's book entitled *Hindu Ethics:* "What troubles Professor McKenzie most is that Hindu ethics is anti-social . . . and that, though anti-social in its asceticism and not spiritual enough, this ethics is in fact better than it ought to be, because Hindu philosophy has predicated a God without attributes and such a God is unmoral and hence by implication should be incapable of inspiring anybody with a logical desire to practice ethical behavior. Professor McKenzie devotes most of his book to upholding this thesis and comes to what seems to be the triumphant conclusion that Hindu philosophical ideas, 'when logically applied, leave no room for ethics'; furthermore, they prevent 'the development of a strenuous moral life.' Incidentally, Professor McKenzie explains that a morality which is not strenuous is not a true morality. One is not really moral unless engaged in active social service. This is perhaps the keynote of his inspiring work." (*Ethics of India,* p. x.)
47. It is the custom among the Hindu Kush people for the women to get together and dance day and night while the men are on a raid. Professor Wright says that they reason as follows: Since the women danced while the men went on a raid and the men were successful, it follows that they were successful because the women danced. "Accordingly it becomes an established custom that the women must dance to ensure the success of raids."
48. Many attacks have been reported by dogs during the last eighteen months.
49. "Frankness is the modern girls' long suit," says an exchange. Apparently it's the only long suit she has. (*Boston Transcript.*)
50. The car was brought to a local garage for repairs and was badly damaged.

CHAPTER II

CLASSIFICATION

Assuming the existence of a mass of data, one of the simplest methods of extending human knowledge is classification. Adopting some fundamental principle of division the investigator arranges the data in an orderly manner on the basis of this principle. When the principle is obtained through a careful and detailed observation of the data to be classified the division is said to be *real*, and when it is a principle adopted because it happens to suit the purpose of the scientist making the classification the division is called *artificial*.

Some sciences, for example botany, zoölogy, and geology, are chiefly concerned with classifying data and with giving accurate *descriptions* of each separate kind or class covered by the division. Hence such sciences are frequently referred to as *classificatory* or *descriptive* sciences. Classification is a basic method of the science of history. (See Langlois and Seignobos, *Introduction to the Study of History*, Book III, Chap. II.) All catalogues are combinations of classification and description. The *Book of Birds*, published by the National Geographical Society, is an excellent illustration of an interesting body of knowledge which employs only classification and description, and many other illustrations could be mentioned. But classification may also serve as a step in other methods of reasoning, and especially in the statistical method (see Chapter IV). In fact it is used extensively in all scientific research.

The ancient method of classifying was *dichotomy* or *binary classification*, so named because it allows only two coördinate classes, one of which is positive and the other negative. Due to this restriction to two main classes this method should be avoided, although it is frequently used.

If the classes of a division overlap, or if there are not enough classes to cover all of the data, the classification is defective. In the former case the fallacy of *cross-division* is committed, and in the latter case the fallacy of *incomplete division*. The latter fallacy may be avoided by having a miscellaneous class, and the former by using only one fundamental principle of division.

WHAT TO READ

One or more of the following discussions of classification should be studied:

Aikins, H. A., *Principles of Logic,* Chap. IV.
Bode, B. H., *An Outline of Logic,* Chap. II.
Columbia Associates, *An Introduction to Reflective Thinking,* Chap. II.
Creighton, J. E., *An Introductory Logic,* pp. 77-83.
Cunningham, H. E., *Textbook of Logic,* Chap. V.
Dotterer, R. H., *Beginner's Logic,* Chap. XI.
Gibson, W. R. Boyce, *The Problem of Logic,* pp. 56-66.
Jones, A. L., *Logic: Inductive and Deductive,* Chap. III.
Joseph, H. W. B., *An Introduction to Logic,* pp. 115-135.
McClure, M. T., *Introduction to the Logic of Reflection,* pp. 141-152.
Mellone, S. K., *An Introductory Textbook in Logic,* pp. 140-149.
Robinson, D. S., *The Principles of Reasoning,* pp. 61-69.
Sayers, W. C. Berwick, *Canons of Classification.*
Schiller, F. C. S., *Formal Logic,* pp. 72-78.
Welton, J., *Manual of Logic,* Vol. I, Chap. VI.
Welton and Monahan, *An Intermediate Textbook in Logic,* Chap. VII.
Westaway, F. W., *Scientific Method,* Chap. XVIII.
Wolf, A., *Essentials of Scientific Method,* Chap. III.

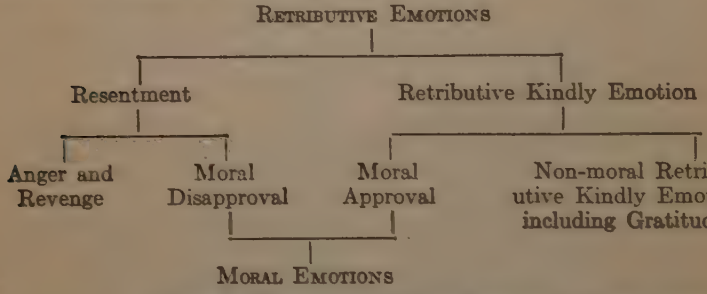
WHAT TO DO WITH THE EXAMPLES

1. The first example is arranged in a classificatory scheme. Make a similar schematic arrangement of examples 2, 4, 5, 10 and 15.
2. Tell whether each classification is real or artificial, and give one reason why you think so.
3. Formulate clearly the principle or principles of division used in each example.
4. Suggest some other principle which could be used to classify the same data.
5. Use this other principle, together with the main one employed in the example, to illustrate the fallacy of cross-division.

6. Criticise the division with the idea of bringing out its strong and its weak points.
7. From what science or sciences do you think each example was taken?

1. The Moral Emotions

The moral emotions are of two kinds: disapproval, or indignation, and approval. They have in common characteristics which make them moral emotions, in distinction from others of a non-moral character, but at the same time both of them belong to a wider class of emotions, which I call retributive emotions. Again, they differ from each other in points which make each of them allied to certain non-moral retributive emotions, disapproval to anger and revenge, and approval to that kind of retributive kindly emotion which in its most developed form is gratitude. They may thus, on the one hand, be regarded as two distinct divisions of the moral emotions, whilst, on the other hand, disapproval, like anger and revenge, forms a sub-species of resentment, and approval, like gratitude, forms a sub-species of retributive kindly emotion. The following diagram will help to elucidate the matter:



Edward Westermarck, *The Origin and Development of the Moral Ideas* (The Macmillan Co., Ltd.), Vol. I, p. 21.

Special Questions

1. Is this a dichotomy?
2. Is the classification complete?

2. Classification of Snakes

There are over two thousand kinds of snakes, most of them tropical, for the majority rely on the heat of the sun to hatch their eggs. In non-tropical climates the common viper gets over this by re-

taining her eggs until they hatch, so that the baby vipers are born fully formed and able to take care of themselves. The grass-snake makes use of the heat generated by rotting vegetation, and that is why its eggs are so frequently found in manure heaps and the stacks of rotting weeds along river banks.

All snakes are cold-blooded, that is to say, their blood-heat is dependent upon the temperature of their surroundings. They have no limbs, although the pythons and two or three other families have vestiges of them. The two halves of their lower jaw are connected together at the chin, and also to the upper jaw, with elastic ligaments instead of bony articulations, and this last characteristic alone may be used to distinguish them from the legless lizards which superficially resemble them in many ways. Many other characters—such as the absence of ears and movable eyelids—are usually included in a definition. The zoölogist places snakes in an order called Ophidia, and further subdivides this into families, genera, species, and varieties. The characters which are used in this scheme of classification require a detailed knowledge of their comparative anatomy, and particularly of their teeth, of which there are an enormous number of different patterns.

In an outline of this kind they are best reviewed in groups as follows:

1. Blind burrowing species.
2. Constrictors.
3. Harmless solid-fanged species.
4. Slightly poisonous back-fanged species.
5. Dangerous front-fanged species.
6. Vipers.

In all the groups excepting 1, there is a great range of variation in form and habitat, including tree-snakes, water-snakes, ground- and burrowing-snakes, of both nocturnal and diurnal habits and every grade of temperament. Some of the most harmless to look at are the most spiteful and venomous, and some really evil-looking ones make charming pets.

Joan B. Proctor in *Discovery*, Vol. VI, p. 448.

Special Questions

1. To what extent does this example combine classification and description?
2. State in a single sentence the definition of a snake given in the second paragraph.

3. How does the zoölogist's principle of classifying snakes differ from that of the author of this example?
4. To what extent is the principle of environment or habitat used in the author's classification?
5. Does his use of the principle of habitat make his classification an example of the fallacy of cross-division?

3. The Elements

The famous Bohr theory of the atom, as developed during recent years, is what makes possible the classification of the elements. Thirty years ago it was thought that atoms were original particles of matter and that iron was composed only of iron atoms, gold only of gold atoms, *et cetera.* We now know that all atoms, no matter what substance, are composed of different numbers and arrangements of the same two kinds of fundamental particles. One is called the electron and the other the proton. Now one group of electrons in an atom is distinguished from all others by the fact that those electrons constituting this group revolve inside the atom in orbits not unlike the orbits of the planets in our solar system. Now there is one kind of atom, one element, for each number of electrons in this orbital group. The first atom—number one in the list—is that of hydrogen. It has one orbital electron. Number two is helium, number three is lithium, and so on. The recently discovered element, *illinium,* is number sixty-one because it has just that number of the orbital electrons. There are ninety-two elements and only two are missing since the discovery of illinium. Atoms above eighty-seven are so unstable in character that they do not hang together well. They appear to have too many orbital electrons.

Forum, Vol. LXXV, illustrated section, p. xxxviii.

4. A Classification of General Intelligence

The methods of mental measurement now make possible the identification of superior intelligence, during childhood. . . . General intelligence in children is classified in various terms. Most often, perhaps, this is at present done in terms of IQ (intelligence quotient), which is the ratio of birthday age to intellectual development. . . . That a child scores at an IQ of 100 means that intellectual development is that of the average child of the given birthday age. An IQ of 100 represents "par," as regards intelligence. A ratio of less than one hundred means some degree of inferiority to the average, while a ratio above 100 means some degree of superiority. The best one per cent of children, as respects intelligence, test at or above 130 IQ,

approximately. . . . It is not known just how widely intelligence can vary in terms of IQ. The most intelligent children reported up to this time test between 180 and 190 IQ, and are, of course, very infrequent.

The Child: His Nature and His Needs (The Children's Foundation), p. 281.

5. The Development of Prehistoric Chronology

The history of the development of a relative chronology for that part of the age of man which antedates history is a good example of how far ahead of their times great thinkers sometimes are, and how long it takes the great mass of their fellows to profit by their achievements. Prehistoric chronology is based on a triple division—the Ages of Stone, Bronze, and Iron. Able thinkers long ago declared such a sequence to have existed, but their conclusions failed to become a part of the common stock of knowledge chiefly because of the tendency of the human mind *en masse* to resist the intrusion of knowledge beyond that which is carried by the traditional current of thought. . . .

The first step in the process of placing prehistoric archæology on a scientific basis was made in Scandinavia. . . . C. J. Thomsen, director of the Royal Danish Museum of Antiquities in Copenhagen, now the National Museum, from 1816 to 1865, was the first paleoethnologist to make use of the methods of geology and paleontology. Seconded by a number of Danish and Swedish scientists, Thomsen succeeded in establishing a relative chronology for prehistoric times, based upon the development of human industry, a chronology which has served as a foundation for all later classifications. After having worked over the problem for twenty years, he divided the prehistoric into the Ages of Stone, Bronze, and Iron, and published his results in 1836. . . .

Thomsen's classification, applied to a great museum, was immediately accepted in Scandinavia and later throughout the world. . . .

When Thomsen published his relative chronology for prehistoric times, the oldest known cultural epoch was called simply the Stone Age. Boucher de Perthes's discovery of a stone industry in the deposits of the Somme valley led to a realization that Thomsen's Stone Age represented only a later phase of the period. On the suggestion of Sir John Lubbock (Lord Avebury), the term *Neolithic* was accepted for this later phase, and *Paleolithic* for the older. Broadly speaking, the Neolithic period was characterized by implements in

which polishing was employed as a final shaping process; the Paleolithic was characterized by the complete absence of polishing as a shaping process. One of the most frequent Paleolithic implements, the flint cleaver (French *coup de poing*, "hand-ax"), crudely chipped on both sides to an amygdaloid or almond-shaped form, was supposed to represent the oldest phase of the Paleolithic Period. These implements occur in undoubted Quaternary deposits, while Neolithic implements occur only in later deposits.

Recognition of the authenticity of paleoliths was scarcely more than achieved when a new struggle broke forth over the question of the nature of certain flints found *in situ* in Tertiary deposits. To the period represented by these pre-Paleolithic, pre-Pleistocene flints, Gabriel de Mortillet gave the name *Eolithic*, a term eminently in keeping with the other two grand divisions of the Stone Age. . . .

The present system of classifying prehistory is the outgrowth, therefore, of nearly a century of extensive and intensive study, especially in the European field, and is primarily applicable to that field. Whether the system can be extended geographically so as to apply without serious changes to other parts of the world occupied by Paleolithic man remains to be seen.

George Grant MacCurdy, *Human Origins* (D. Appleton & Co.), Vol. I, Ch. I.

Social psychologists find the classification of the periods of prehistory made by the anthropologists unsatisfactory. Thus Professor Charles H. Judd writes:

6. A Criticism of the Preceding Classification

It has been the practice of historical anthropology to designate the successive steps of civilization by the names of the materials used in making weapons and tools. Thus the earliest ages are called stone ages, later came ages of bronze and iron; our own age is often spoken of as the age of steel. Another method of classifying epochs in human evolution is by reference to the predominant industry. There was a period when men supplied themselves with food chiefly by hunting. Later came agriculture and herding and finally manufacture. These methods of classifying different stages of civilization have the virtue of being based on objective facts. One can readily determine by an examination of the remains found in caves and on the sites of ancient villages what materials man was using in the construction of his implements. There is, however, a disadvantage

in emphasizing material facts and regarding these as the typical facts in human history. The truth is that man of the stone age was limited to the use of stone because his experience had not yet reached the stage where he was acquainted with metals.

CHARLES H. JUDD, *Psychology of Social Institutions* (copyright, 1926, by the Macmillan Co.; reprinted by permission), p. 5.

7. The Layers of Peat Bogs

A typical section through a south Scandinavian bog shows six layers. The lowest layer (*a*) consists of fluvio-glacial sands. Above this is (*b*) tree-stumps, mainly birch, but with some oak (*c*). Then comes a thick layer of peat (*d*), followed by a second layer of tree-stumps (*e*), representing a mixed forest in which the oak predominated. Finally we have a second thick layer of *Sphagnum* peat (*f*), dried and weathered at the top. The obvious interpretation of this sequence is that after a short cold period the climate became sufficiently dry and warm in summer for a birch forest to grow. Then followed a wet period in which peat killed the forests, followed by a second splendidly dry and warm period in which rich forests were able to grow even on the dried-up surface of the bogs. Again the climate deteriorated, and the forests died. In the last few centuries there has again been a turn for the better. This sequence was discovered in 1876 by the Norwegian, Axel Blytt, who devised the nomenclature: Boreal (the first dry period), Atlantic, sub-Boreal, sub-Atlantic. It is true that the sequence has been explained also by the mechanics of water supply in a peat bog, but the phenomena are so general over wide areas, and fit in so well with other types of evidence, that there is no doubt that the climatic explanation is the correct one. On land which emerged from the sea after the Boreal period was over the sequence did not begin at the beginning; only one forest layer is present, which can be recognized as the sub-Boreal, and this fact enables us to correlate the peat-bog sequence with the changes of level. The peat-bog sequence is confirmed by the deposits of calcareous springs, many of which dried up during the Boreal and sub-Boreal periods and became very active in the Atlantic and sub-Atlantic. The fluctuations of small lakes tell a similar story. When all this evidence is considered together it will be seen that the post-glacial fluctuations of climate in northern Europe have been proved over and over again. Perhaps the most remarkable point in the story is that the genius of Axel Blytt made out all this sequence from the details of the distribution of living

animals and plants alone, and he merely went to the raised beaches and the peat bogs to confirm his views.

The great peat bogs of Ireland show a generally similar sequence, but without the sub-arctic bed; the layer (*e*) is especially interesting, for its rich archæological remains dating from the late Neolithic and Bronze Ages. During the growth of the lower peat layer, Neolithic man lived on the sand dunes, but in the very dry sub-Boreal period he migrated to the dried surface of the peat bogs. A two-story log house has been discovered in Drumkelin Bog. In the following wet period the settlement was smothered by the bog and the roof of the hut is covered by twelve feet of peat.

C. E. P. Brooks in *Discovery*, Vol. VI, p. 472.

Special Questions

1. What are the two different classifications in this example?
2. How is the second related to the first?
3. What is the principle on which each is based?

8. Post-Glacial Geology

It is well known that the greater part of the Arctic Ocean is covered by a floating mass of ice, of which only the fringes break up in summer. The temperature of the air above this ice is very low—near the North Pole it is about −30° F. in January—but recent calculations have shown that this low temperature is almost entirely produced by the ice. If the ice could be swept away the mean temperature even in mid-winter would be about 27° F. Let us call this the "akryogenous" (iceless) temperature. If the ocean were free of ice and the akryogenous temperature were only 5° F. higher than at present, the Arctic Ocean would not freeze. When an ice-cap has once been formed, its mere presence suffices to lower the actual temperature by some 50° F., and this makes it very stable, and able to survive minor changes of climate, just as it survives the seasonal change from winter to summer. Hence to sweep it away the akryogenous temperature must be well above 28° F. (the freezing point of sea water) for a number of years. This happened during the sub-Boreal period. Even between about A.D. 260 and 1200 the ice conditions were much less severe than they are now. During the latter part of this period the Norsemen were colonizing Greenland, and Pettersson has pointed out that their records contain very little reference to floating ice.

On these lines we may write the history of the post-glacial period as follows: The Ice Age ended about 6500 B.C., but it left the Arctic Ocean filled with floating ice. About 4000 B.C. depression of the North Atlantic regions let a flood of warm water into the Arctic Ocean, which swept away this ice-cap, and a period of dry climate set in, with moderate winters and hot summers. The oceans warmed up, this and the melting back of the ice-sheets beyond their present limits raised the general sea-level, and the Climatic Optimum about 1500 B.C. is marked in almost all parts of the world by beaches about ten feet above the present beaches. About 850 B.C. the supply of heat fell off for some reason, and the Arctic Ocean again became glacial. After 100 B.C. the Arctic ice-cap gradually broke up, although, except possibly for a short time in the seventh century, it did not entirely vanish. The final stage set in about A.D. 1000 with a second renewal of the ice-cap, associated quite definitely this time with an increase in the sun's spottedness, and this stage has continued to the present day.

Discovery, Vol. VI, p. 474.

9. A Division Criticised

The all-black and the all-white method of judging the past makes its periods either all wheat or all tares. Thus the War has caused many to speak as though it ended in an irreversible verdict for eternal wrong, and those who went into it with clean hands to end it were equally guilty with those who plotted and precipitated it. Others refer to the Victorian era as one of self-seeking materialism projected upon calamitous lines. The politics of Central Europe, and, to a lesser degree, those of Britain and North America are described as agitated by greed, hatred, hypocrisy. It is also urged that the catastrophe which fell upon the age was at once its condemnation and penalty. So much for the artist who thinks in sepia and paints in unrelieved blackness "sweat-shops, conscienceless capitalists and human bondage." Those of the white school ask us to admire commanding figures of the period, aristocratic rulers in every realm, moving in the serenity of which Tennyson was the singer. An impartial historian, Lecky, gives it as his opinion that no country was ever better governed than Britain between 1832 and 1867. Most Americans would also say the same of Lincoln's America; an interval, be it observed, marked by our Civil War, and by the goading of Britain's manual workers into successful revolt against penury and starvation. Those who would live hopefully should

not accept the black or the white interpretation of history. Half the charm of history, and far more of its truth, consists in its infinite shadings, contrasts, high or low lights, and paradoxical situations.

S. Parkes Cadman, *Christianity and the State* (copyright 1924 by the Macmillan Co.; reprinted by permission), p. 43.

Special Questions

1. What is Dr. Cadman classifying in this passage?
2. What is the real basis of the fallacy he points out?

10. Babies Display Temperament in Personality Test

That children as young as two and three years of age can be sorted out according to emotional temperament, has been shown by an experiment with 100 children from two to six years old, conducted by Dr. Leslie R. Marston, at the Iowa Child Welfare Research Station at the University of Iowa.

The experiment, which has just been reported, shows that the two year old, who can scarcely talk, is already developed into a personality type so marked in character that habitual emotional reactions may be expected.

Dr. Marston classifies the young subjects of his experiment into introvert and extrovert types, a division commonly used in analyzing character. An extrovert of any age expresses his emotions in actions, while the introvert inhibits expression and uses his emotional energy within his own body.

The term introvert, "turned inward" suggests the person whose center of attention is himself. According to the rating scale, the introvert is habitually selfconscious and easily embarrassed; he is reserved and prefers to work and play alone, is sensitive, modest, and yields to others rather than oppose them. He is careful and good at details, deliberative, slow and tends to stay in a rut and avoid new situations. He underestimates his own ability, is moody and worries. The extrovert, whose emotions and thoughts are "turned outward," has the opposite characteristics.

The children were rated in 20 traits according to this scale, in addition to the introverts and extroverts, some of the children were classed as an in-between type, called by Dr. Marston the ambiverts—"turned both ways"—who are introvert in some particulars, extrovert in others, but less extreme in their reactions than the true introverts and extroverts.

Daily Science News Bulletin, No. 240A.

Special Question

Do you think that Dr. Marston succeeded in avoiding the fallacy of overlapping by introducing his third coördinate class—ambiverts?

11. Shamrock Remains a Plant of Mystery

The shamrock, popularly accepted as the national emblem of Ireland, and worn the world over on St. Patrick's day, will probably always remain a mystery and a puzzle to botanists. It cannot properly be called Ireland's national flower, because only the leaf is used as the symbol, and it is not certain which of several flowers the leaf belongs to.

The commonest statement is that the shamrock is identical with ordinary white clover, but that it grows more luxuriantly in Ireland because of the moist and equable climate of the island and its generally favorable soil. Another claim is made in favor of a yellow-flowered clover, known outside of Ireland as the "non-such." A third plant that bears the old Irish name of "seamrog" is the wood sorrel or oxalis. This species is more nearly related to the violets than it is to the clovers, but its leaves, like those of the clovers, are three-parted. At least one of the medieval Irish herbals, or books of medicinal plants, ascribes great curative virtues to the plant, which, unfortunately, are quite imaginary.

The shamrock is not the only plant famous in antiquity whose modern classification is in doubt. Ancient and medieval botanists identified their plants and reckoned their relationships largely by means of their leaves, so that to the learned men of old times in Ireland any tri-foliate plant was a "seamrog" or shamrock. Modern botany broke up this ancient classification by arranging plants according to their flowers and fruits rather than their leaves, so that now we have several clover "shamrocks" and at least one oxalis "shamrock." Just which of these it was whose leaf St. Patrick plucked in his famous theological dispute will probably never be known.

Daily Science News Bulletin, No. 259E.

12. No Naturally Bad Children

Children are not bad by nature, declares Dr. Edgar A. Doll, an authority on child psychology, who discusses child conduct in *Hygeia,* a popular health magazine published by the American Medical Association (Chicago). A child's conduct, he says, is called good or bad as it makes life easier for adults or puts us to

inconveniences. It is difficult for parents or teachers to apply a standard of conduct based on the child's intent or the child's welfare rather than their own convenience, comfort or pleasure. When, therefore, the conduct of children conflicts with our own immediate happiness, we are prone to ascribe some malicious intent and to look for antisocial motives. Dr. Doll goes on:

"Children commonly fail to do what we consider the right thing, because they fail to understand what is desired of them. They have not been adequately instructed, they have misunderstood, or they have lacked intelligence to understand or to judge well. We must not forget that example is stronger than precept, and that many of the undesirable activities of children are the result of imitation of other children whose social training has been neglected or unsuccessful.

"But the study of intelligence does not explain all the difficulties of child behavior. More recently we are beginning to understand that the emotions of children play a much more powerful part in determining conduct than has previously been supposed. We have been inclined to look on children's emotions as consequences of their actions. We are beginning to understand that these emotional disturbances may be the most important determiners of child behavior. Emotional instability is now seen to be both the cause and the effect of misconduct, thus creating a vicious circle of ever-widening scope."

Four types of emotional disturbances are found in children, according to Dr. Doll. These are:

"1. Those that are normal to the growing child and reflect the natural influences of the development of his personality.

"2. Those caused by some abnormal physical condition, usually subject to remedial treatment or correction.

"3. Those arising from strictly social causes.

"4. Those due to unfortunate mental organization such as conflicts, attitudes, faulty habits, uncontrolled instincts."

Literary Digest, Oct. 31, 1927, p. 21.

Special Questions

1. Make a classification of the determinants of the child's conduct.
2. What is the value of this classification for those who have to do with children?
3. How does the principle of division used by Dr. Doll differ from the principle used by many parents and teachers? Which do you think is the more scientific and why?

13. Classifying the Stars

A simple system of designating the various classes of stars by the best known of all symbols, the alphabet, was originated by Professor E. C. Pickering, and has been adopted by the whole astronomical world. Let us see how some of the familiar stars are thus lettered.

When an astronomer speaks of a Class *A* star, he refers to white stars like Sirius and Vega, in whose spectra we see a very strong series of dark lines caused by hydrogen in the atmosphere. For blue-white stars like Rigel we use the letter *B*. The gas helium, so precious and so scarce here on Earth, is very abundant in the atmospheres of these stars. The letter *G* is used for our own Sun and other yellow stars; and for red stars like Betelgeuse we use the letter *M*. Between *A* and *G* are the *F* stars; and between *G* and *M*, the *K* stars. Other letters designate several rarer varieties. After a large number of stars had been classified, it was found that the letters *B, A, F, G. K, M,* stand for six divisions including the great majority of the stars. *B* must go before *A* in the astronomers' alphabet, because when it was too late to reverse the letters, the *B* stars were found to precede the *A* stars in life-history. Thus we have the so-called *BAF* classification, which is easy to remember, said an Irish astronomer, because *BAF* stands for Baffling.

Arranged in the given order, with intermediate divisions, the letters represent stars classified according to decreasing temperature and increasing redness.

The Universe of Stars, pp. 105 *f.* (Harvard Radio Talks).

The stars grow more numerous as they become less significant. We know only twenty-one stars which we consider brilliant enough to put in the top class and call stars of the first magnitude. Stars a little fainter, some fifty in number, are called stars of the second magnitude; those still fainter of the third magnitude, and so on. Stars of each magnitude class are two and one-half times fainter than the stars of the preceding class, so that stars of the sixth magnitude are one hundred times fainter than those of the first. Further, stars of the eleventh magnitude, are ten thousand times fainter, and stars of the twenty-first magnitude, which is the lower limit of penetration of our present day telescope, one hundred million times fainter than stars of the first magnitude.

Idem, pp. 118 *f.*

Special Questions

1. What bearing does the expression "when it was too late to reverse the letters, the B stars were found to precede the A stars in life-history" have on the question of whether this is an artificial or a real division?
2. Is the second classification based on the same principle of division as the first?
3. To what extent does the first classification use description?

14. A Classification of Superstitions

Superstitious beliefs may roughly be divided into those that are based on actions and those founded on some material object such as a fetish or charm. There are many other ways in which superstitions can be classified: some are prophylactics to prevent evil, others are charms to coerce "good luck." In the present brief study two classes may be distinguished. In the first belong those that are adopted as the result of suggestion, the common beliefs in knocking wood, in the number 13, a post intervening between friends, breaking mirrors, and others of that type. The second class is much more interesting, and includes those which are individual, and due, in general, to no outside influence. They came into the mind privately, and hold a place there usually unknown to anyone else. Imaginary lines running out at right angles from pieces of furniture which must be avoided, and reaching a definite place before some event occurs, are examples of this type.

Fetishes may be placed in the same two categories (classes); the rabbit's foot and the horseshoe are suggestion-made charms; many fetishes, however, are selected as seats of power owing to no suggestion from others, but due to the supposed "run of luck" coming from association with these objects. In this type a man does not start out and say he is going to have this or that as his fetish. He is fortunate in some undertaking and, reasoning backward, he tries to find something which is responsible for his success.

A. M. Tozzer, *Social Origins and Social Continuities* (copyright, 1925, by the Macmillan Co.; reprinted by permission), pp. 242 *f.*

Special Questions

1. Why does the author use the expression "roughly divided"?
2. Are there two or three principles of division suggested in this example?
3. What fallacy is suggested in the last sentence? (See above, p. 7.)

15. A Classification of Manufacturing Costs

The Federal Trade Commission as a result of its exhaustive research and study of the cost of production of a large number and variety of businesses, presents in document No. 1356 entitled "Fundamentals of a Cost System for Manufacturers," a simple yet complete analysis of manufacturer's costs.

The three elements of cost are *Material, Labor, and Overhead Expense*. The first two of these are divided into direct and indirect.

Direct Material is that which forms part of some particular job, or which can be charged directly to a unit of product. Indirect material is that which cannot be located as belonging to any job or unit.

Direct Labor is that which is applied directly to a particular job or unit of product. Indirect labor is that which cannot be located as belonging to any particular job or unit, as the labor of a works manager or superintendent of foremen.

Direct Material and Direct Labor constitute what is generally known as *Direct* or *Primary Cost*, and show the actual amount of cost directly chargeable to a particular job or unit of product.

Overhead Expense is expense of every kind connected with the business, none of which can be located as belonging to a particular job or unit. These expenses, while part of the cost, are general, and therefore cannot reach the job or unit directly, hence a method must be devised for them to reach the cost sheet indirectly, and in such a manner that each job or unit will receive its fair proportion of the total. For this reason overhead expense is sometimes termed indirect cost.

Overhead expense is divided into two classes, *Factory Overhead*, which consists of items directly belonging to factory production, *General Overhead*, which is expense not directly connected with the factory.

Factory overhead is split into two parts, *Fixed* and *Variable* charges. Fixed charges consist of building expense or rent, power, insurance, taxes, and depreciation. Variable charges, the controllable expenses of factory operation, complete factory overhead, and include such items as indirect labor, repairs, lubricating oils and miscellaneous supplies.

Direct cost plus factory overhead constitutes what is usually termed *Factory Cost*.

The next step, now that the goods are completed and placed in

the storeroom as finished goods, is to compute their share of *General Overhead,* which consists of the shipping, selling, and *General Expenses* of the business.

Shipping Expense includes a proportion of fixed charges, freight or drayage, shipping clerks' wages, supplies, and incidental expense items.

Selling Expense involves such items as salaries and expenses of sales force on the road and in the office, advertising, catalogues, cost of handling cancelled orders, etc.

Last but not least come *General Expenses,* such as officers' salaries, office expenses, insurance, defective work, taxes, interest when charged and other items of a general nature.

With the adding of general overhead to factory cost the riddle is solved and *Total Cost* is found—this plus profit constitutes the *Selling Price.*

HENRY P. SHEARMAN, *Practical Economics* (McGraw-Hill Book Co., Inc.), pp. 174-176.

Special systems of classification have been devised to classify complicated data consisting of thousands of items. The alphabet system of classifying the stars (No. 13 above) is an example. Melvil Dewey invented the Decimal System of classifying books and it has come into quite general use in public libraries. The main divisions are as follows:

16. The Dewey Decimal System of Classification

000 GENERAL WORKS	500 NATURAL SCIENCE
010 Bibliography.	510 Mathematics.
020 Library Economy.	520 Astronomy.
030 General Cyclopedias.	530 Physics.
040 General Collections.	540 Chemistry.
050 General Periodicals.	550 Geology.
060 General Societies.	560 Paleontology.
070 Newspapers.	570 Biology.
080 Special Libraries. Polygraphy.	580 Botany.
090 Book Rarities.	590 Zoölogy.
100 PHILOSOPHY	600 USEFUL ARTS
110 Metaphysics.	610 Medicine.
120 Special Metaphysical Topics.	620 Engineering.
130 Mind and Body.	630 Agriculture.
140 Philosophical Systems.	640 Domestic Economy.

150 Mental Faculties. Psychology.
160 Logic.
170 Ethics.
180 Ancient Philosophers.
190 Modern Philosophers.

200 RELIGION

210 Natural Theology.
220 Bible.
230 Doctrinal Theology.
240 Devotional and Practical.
250 Homiletic. Pastoral.
260 Church. Institutions. Work.
270 Religious History.
280 Christian Churches and Sects.
290 Non-Christian Religions.

300 SOCIOLOGY

310 Statistics.
320 Political Science.
330 Political Economy.
340 Law.
350 Administration.
360 Associations and Institutions.
370 Education.
380 Commerce, Communication.
390. Customs. Costumes. Folklore.

400 PHILOLOGY

410 Comparative.
420 English.
430 German.
440 French.
450 Italian.
460 Spanish.
470 Latin.
480 Greek.
490 Minor Languages.

650 Communication.
660 Chemical Technology.
670 Manufacturers.
680 Mechanic Trades.
690 Building.

700 FINE ARTS

710 Landscape Gardening.
720 Architecture.
730 Sculpture.
740 Drawing. Design. Decoration.
750 Painting.
760 Engraving.
770 Photography.
780 Music.
790 Amusements.

800 LITERATURE

810 American.
820 English.
830 German.
840 French.
850 Italian.
860 Spanish.
870 Latin.
880 Greek.
890 Minor Languages.

900 HISTORY

910 Geography and Description.
920 Biography.
930 Ancient History.
940 Europe.
950 Asia.
960 Africa.
970 Modern North America.
980 South America.
990 Oceanica and Polar Regions.

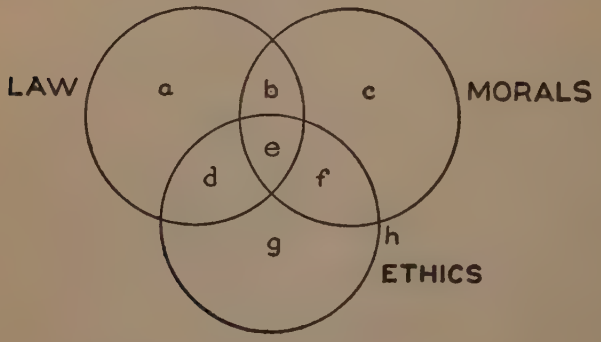
Special Questions

1. Would any of these ten divisions overlap? If you think they would, give examples.
2. Criticise the arrangement of the sub-classes under philosophy.
3. Rearrange the sub-classes under religion according to some definite principle.

4. Mention two or three ways in which this classification could be expanded.
5. Where would you put a book on eugenics, on athletics, and on measles, and why?

17. Types of Human Conduct

One may regard the three fields of law, morals, and professional ethics as overlapping but partly distinct spheres of activity. For example, the fugitive slave laws enacted before the Civil War were regarded by some as legal, but immoral, (*a*); so also today with



most so-called "blue laws." In regard to such acts as forgery and murder (*b*) we find both moral condemnation and criminal liability. And yet it is questionable whether any of these four acts falls strictly within the sphere of professional ethics other than as the prerequisite which might be demanded of any gentleman in society. A third class of cases includes indolence and sexual immorality, (*c*) falling clearly within the moral field but being practically unrecognized by the law and seldom mentioned in codes of professional conduct; except in "vagrancy" laws and professional canons urging "diligence." Contempt of court is clearly an illegal act (*d*) and is recognized by lawyers as flagrant unprofessional conduct. A great many people, however, might regard such action as a matter solely of legal or professional concern, except in so far as all contempt for law is immoral. In this same class of cases may be listed "practicing a profession without a license;" this is at once illegal and unprofessional, but it would hardly be regarded as immoral by certain individuals who have been benefited by legal advice, medical

help, or spiritual guidance offered by men who do not happen to be licensed in the profession.

Many acts fall within the class of cases (*e*) which are illegal, immoral, and unprofessional. Deceiving a judge in regard to evidence and any malfeasance of professional trust are but two of the many cases which occur in this group. If we now consider those actions which the law does not take cognizance of, we may discover situations which are both immoral and professionally unethical (*f*). So, for example, is professional carelessness, a mild form of which is the failure to be punctual in the keeping of appointments, or the matter of "privileged communications." Charity in the form of providing counsel for indigent prisoners and medical attention to persons who cannot pay are recognized both as moral and are specifically provided for in professional codes. A class of cases (*g*) which may be regarded as falling within the professional code but which are not necessarily immoral is represented by the practice of advertising and by the practice of communicating or not communicating to a client any disagreements in consultations. Even among the realty brokers advertising has come to be a matter which must be controlled. The restriction of this practice by professional pressure among doctors and lawyers is indeed much greater than the law possibly could accomplish. A final class of cases must be cited (*h*): What shall we do with such matters as neat appearance and religious beliefs or attendance at church? Obviously these are not matters for the law; not many professional codes include statements regarding them, while in a great number of cases these matters could clearly be regarded as falling outside the field of personal or social morality.

Thus we have cited eight classes of cases which logically exhaust the possibilities of the three fields of human relationship: law, morals, and professional ethics.

CARL F. TAEUSCH, *Professional and Business Ethics* (Henry Holt & Co.), pp. 79*f*.

CHAPTER III

THE METHOD OF SAMPLING

When the material with which the investigator has to deal is so extensive and involved that the enumeration and observation of each separate item is impractical or even impossible, the method of *sampling* is usually employed. This method consists in selecting a representative set of instances of the material in question, determining by careful observation what the general character of this set is, and inferring that the entire mass will be of the same nature as the samples. In order for this conclusion to be reliable the samples must be chosen at random. This means independently of each other and of the wishes or prejudices of the investigator. Such instances are said to be *fair samples.*

An important assumption underlies this method. If the material being investigated is homogeneous the assumption is that it will have the same character as the samples, and if it is heterogeneous the assumption is that the variety which the samples reveal will hold for the entire collection of data. A briefer way of expressing this assumption is to say that the entire lot sampled will be like the samples.

To make the inference from the samples to the entire lot more trustworthy scientists sometimes "sample the samples." Such a procedure is really a double use of the method of sampling. For example, when a chemist samples coal to ascertain its quality he first takes fair samples from each carload, he then pulverizes all of these samples into a single heap, and from this he takes another set of fair samples for chemical analysis. This enables him to get a more exact knowledge of the quality of the coal he is asked to judge.

This method has recently been widely extended. Vocational psychologists have employed it in constructing voca-

tional tests. Candidates for positions are given sample jobs and their ability to fill the position for which they are applying is judged by their success in performing these sample jobs. Bacteriologists use it in the study of bacterial diseases. Professor Raymond Pearl, in a recently published book entitled *The Biology of Population Growth*, has used sampling to determine what he calls the law of population growth. Starting with pairs of insects he grew sample communities of these animals in milk bottles until the number exceeded the food supply and all died. The law which he derived from observing these sample communities of insects he applied to human communities, thus combining sampling with the method of analogy which is dealt with below (Chapter V). Like classification, sampling is frequently used in statistical method. Hence this method is of great significance in scientific research.

WHAT TO READ

The literature for beginners on the method of sampling is very scarce, due to the fact that this method has been developed within recent years or since most of the elementary textbooks in scientific method were written. There is an excellent chapter, especially oriented to vocational psychology, in Professor H. L. Hollingworth's *Judging Human Character* (D. Appleton & Co.), p. 151. I have expounded the method in my *Principles of Reasoning*, Ch. XVIII. (See also pp. 207*f*.) Students should read both of these discussions and teachers may find Josiah Royce's article entitled "Logic," in Vol. I of W. Ruge's *Encyclopedia of the Philosophical Sciences*, suggestive, but it is too difficult for beginners. See also A. Wolf, *Essentials of Scientific Method*, pp. 112-115.

WHAT TO DO WITH THE EXAMPLES

1. For each example state what the material sampled is.
2. Do you think that this material is of such a nature as to justify the assumption that the whole is like the samples?
3. How many samples are used in each example? Where only a few are used make a list and describe each sample (sample number 1 and 2, etc.).
4. What reasons can you give for regarding each as a "fair sample"?

5. State which of the examples uses the double method of sampling and explain why you think so.
6. Make any criticism you care to make on the procedure used in any example. Give your opinion as to the validity of the inference.
7. Name the science or sciences from which each example has been selected.

1. Studying Sand Grains

Even a sand grain must travel to become well-rounded and acquire a polish. It must travel extensively, too—for most sand grains a journey from the center of the continent to the ocean, twice repeated, is necessary. Voyages by water smooth off the grains more rapidly than air travel, and even when travelling by wind, they rub each other only when they are rolling along the ground.

These are among the results of a three-year's study of sand grains conducted by Professor Gustavus E. Anderson of the University of Oklahoma. The immediate objective of his research was to gain some light on the origin of sandstone deposits, especially the oil-bearing sandstones. It is often of great importance, Professor Anderson stated, for the oil prospector to know whether a given sandstone formation was laid down as wind-blown or as water-borne sand, and up to the present practically no laboratory investigations have been conducted to check up on the numerous extant theories.

Professor Anderson simulated field conditions by tumbling sand samples of various types in bottles on rotating drums, some of the bottles containing sand in water, others sand without water. By keeping them constantly on the move, he was able to get in a few hundred hours the same effects that in nature require many hundreds of years.

Daily Science News Bulletin, No. 237E.

2. The Motion of Glaciers

We now approach an epoch in the scientific history of glaciers. Had the first observers been practically acquainted with the instruments of precision used in surveying, *accurate* measurements of the motion of glaciers would probably have been earlier executed. We are now on the point of seeing such instruments introduced almost simultaneously by M. Agassiz on the glacier of the Unteraar, and

by Professor Forbes on the Mer de Glace. Attempts had been made by M. Escher de la Linth to determine the motion of a series of wooden stakes driven into the Aletsch glacier, but the melting was so rapid that the stakes soon fell. To remedy this, M. Agassiz in 1841 undertook the great labour of carrying boring tools to his "hotel," and piercing the Unteraar glacier at six different places to a depth of ten feet, in a straight line across the glacier. Into the holes six piles were so firmly driven that they remained in the glacier for a year, and in 1842 the displacements of all six were determined. They were found to be 160 feet, 225 feet, 269 feet, 245 feet, 210 feet, respectively.

A great step is here gained. You notice that the middle numbers are the largest. They correspond to the central portion of the glacier. Hence, these measurements conclusively establish, not only the fact of glacier motion, but that the *centre of the glacier, like that of a river, moves more rapidly than the sides.*

With the aid of trained engineers M. Agassiz followed up these measurements in subsequent years. His researches are recorded in a work entitled *Système glaciaire,* which is accompanied by a very noble Atlas of the Glacier of the Unteraar, published in 1847.

These determinations were made by means of a theodolite. . . . The same instrument was employed the same year by the late Principal Forbes upon the Mer de Glace. He established independently the greater central motion. He showed, moreover, that it is not necessary to wait a year, or even a week to determine the motion of a glacier; with a correctly-adjusted theodolite he was able to determine the motion of various points of the Mer de Glace from day to day. He affirmed, and with truth, that the motion of the glacier might be determined from hour to hour. . . . Professor Forbes also triangulated the Mer de Glace, and laid down an excellent map of it. His first observations and his survey are recorded in a celebrated book published in 1843, and entitled *Travels in the Alps.*

These observations were also followed up in subsequent years, the results being recorded in a series of detached letters and essays of great interest. These were subsequently collected in a volume entitled *Occasional Papers on the Theory of Glaciers,* published in 1859. The labours of Agassiz and Forbes are the two chief sources of our knowledge of glacier phenomena.

JOHN TYNDALL, *The Forms of Water* (D. Appleton & Co.), pp. 60*f.*

3. Typhoid Germs Live in Ice Cream

Continued freezing apparently cannot kill the bacteria that cause typhoid.

Professor M. J. Prucha and J. M. Brannon, of the department of bacteriology of the University of Illinois, kept a colony of typhoid germs in a sample of ice cream at a temperature averaging four degrees below zero for two years. From time to time samples were taken out, for all of which positive cultures were obtained. The number of bacteria decreased gradually, it is true, but as many as 11,000 living typhoid bacteria survived in the final sample at the end of two years.

In their paper in the *Journal of Bacteriology* the authors conclude from these results that low temperatures cannot be relied upon to destroy typhoid germs in ice cream. They do not attempt to explain the resistance of the organisms to low temperature but there is indication, they say, that the kind of medium in which they are grown is an influential factor.

Daily Science News Bulletin, No. 262A.

4. Arsenic in Apples

To depend upon wind and rain for the removal from the surface of apples of the arsenical compound used in spraying is surely light-hearted and there is the further danger of diffusion into the substance of the fruit. The recent prosecutions of Hampstead (England) tradesmen for selling Jonathan apples containing from one-thirtieth to one-fifteenth of a grain of arsenic to a pound of apples show that the danger is a real one. Out of sixteen or seventeen samples purchased five contained one one-hundreth of a grain or upward of arsenic.

Literary Digest, Feb. 20, 1926, p. 26.

5. Measuring Lightning Voltage with the Lightning Generator

Mr. F. W. Peek, writing in the *Manufacturer's News* (Chicago), tells how the destructive power of lightning is measured. He says:

"The lightning generator has been of considerable help in gaining a knowledge of natural lightning. In fact, it has afforded a means of estimating the voltage of a real lightning stroke. The means were very simple and will be cited as an example of the general method of the research, which was to observe natural lightning and then observe artificial lightning on models built to scale in the laboratory.

"The voltage of a real lightning stroke can not be directly measured by placing a meter between cloud and earth. However, for any given flash, the lightning voltage induced on a transmission line can be measured. The length of the flash and the cloud arrangement with reference to the line can be estimated closely. A model cloud and line were constructed to scale for a case where the measured voltage on the real line was 1,000,000 volts. Discharges were produced on the model from the lightning generator. The voltage on the model cloud could be measured, as could the induced voltage on the transmission line. It was found that under these conditions 1 per cent of the lightning was induced on the line. If the 1,000,000 volts induced on the real line was 1 per cent of the lightning voltage, the voltage of the flash must have been 100 $\times$ 1,000,000 or 100,000,000 volts. Of course lightning voltages vary, but this gives a good idea of the order of a severe lightning stroke. It is estimated that the current was about 60,000 amperes, and the energy 13,000 kilowatt-seconds or 3.6 kilowatt-hours. The flash occurs when the voltage along the discharge is 100,000 volts per foot. The voltage of lightning is thus about one million times the voltage of the ordinary lighting circuit, or one thousand times the voltage of very high voltage transmission lines. The energy in a good flash is sufficient to operate an automobile about five miles, or an electric toaster for a day."

Literary Digest, May 9, 1925, p. 24.

Special Questions

1. Is it justifiable to use samples of artificial lightning to infer the amount of voltage of natural strokes of lightning?
2. If so, would this hold of all characteristics of artificial lightning or only for voltage? For example, could the degree of brightness of a flash of natural lightning be determined from samples of artificial lightning made by a lightning generator?

6. Testing Insulin

There is only one way of discovering whether insulin which has been prepared is properly active, and that is to see if a sample of it will cause the disappearance of sugar from the blood. For this purpose a rabbit is used. In order that the percentage of sugar in the blood may reach some standard value the rabbit has first to be starved for twenty-four hours. A sample of its blood is then taken, an injection of insulin made, and after some hours another

sample is taken. If the percentage of sugar in the blood has dropped enough it shows that the sample of insulin is up to standard.

Discovery, Vol. VI, p. 49.

7. Social Circulation in Petrograd

With the assistance of my pupils I carried out in 1921-22 an investigation of the social circulation in Petrograd, during the years of the revolution. Eleven hundred and thirteen persons were subjected to investigation. The main results are as follows: Of those 1113 persons every one had at least once changed his original occupation in the period from 1917 to 1921. Having summed up the total number of changes of professions, I divided that figure by 1113, and thus obtained the average number of changes of profession which amounted to five. Even for America, not speaking of Petrograd, such a rate of professional circulation would be abnormal.

A similar process went on as regards the legal and proprietary displacement of these persons. All of them were removed from the old places. The majority became impoverished; a comparatively small section became rich. Their "social position" also changed sharply.

Two examples will prove the rapidity and sharpness of those changes. A former Senator and Deputy-Minister, during three and a half years of the revolution, has passed consecutively through the following stages: A starving gardener, a prisoner in a concentration camp, a dealer in powder against cockroaches, a clerk in a co-operative shop, a typist in the Academy of Sciences, a teacher in the Agronomic School, a member of the Board of an Agricultural Association, a photographer. A former village lad, eighteen years old, had been consecutively in those years: A Red Army soldier, a factory worker, a party propagandist, arrested and condemned to death by the Whites, a member of a factory committee, an administrator of finances in a provincial town, a Red Army officer, a student, a member of the Provincial Committee of the Russian Communist Party, chairman of the Provincial Extraordinary Commission, a member of the All-Russian Central Executive Committee and a prosecuting counsel.

Although not all those people had so many changes as these two, yet at any rate all of them passed through more vicissitudes than they did in normal times. It is precisely during revolutions that, as the song goes, "Fate is playing with men; now it elevates them, now it throws them into an abyss."

Such is the picture of revolutionary circulation seen with the aid of a microscopic analysis. It is but a miniature copy of what is going on on a large scale among the Russian population.

PITIRIM A. SOROKIN, *The Sociology of Revolution* (J. B. Lippincott Co.), pp. 238-239.

8. Bacteria Discovered in Oil Wells

First direct evidence of the existence of living things a thousand feet or more beneath the surface of the earth is claimed by Dr. Edson S. Bastin, head of the department of geology at the University of Chicago, and his associates Frank E. Greer and Gail Moulton.

During the last summer the party, working in coöperation with the Illinois State Geological Survey, made chemical and bacteriological analyses of the oils and associated waters from twenty-five oil wells of southern Illinois. The samples were taken from continuously flowing wells, the depths of which range from 500 to 1500 feet below the surface. In twenty-three out of the twenty-five samples, cultures made in the University bacteriological laboratory show an abundance of bacteria.

Daily Science News Bulletin, No. 239F.

9. Winged Tree Seeds Proved Good Travelers

That the winged seeds of the Douglas fir, principal timber tree of the Northwest, can travel surprising distances in even a moderate wind has been demonstrated by an experiment performed by the foresters of the Pacific Northwest Experiment Station at Pearson flying field. According to the government scientists, this test yielded data of value in determining the number of trees which should be left for reseeding purposes when an area is cleared of its timber.

In the experiment, a box kite carrying a carton of Douglas fir seed was sent up in an eight-mile wind, and when it had reached the height of a full-grown cone-bearing tree the seeds were released by a suitable mechanism. Observers stationed by canvas sheets spread on the ground at various distances down the wind watched the flight of the seeds, and counted the numbers falling on their sheets, from which the number of falling seeds per acre were calculated.

The winged seeds, their downward flight retarded by the spinning motion given them by their wings, formed a tiny cloud which floated

down the wind taking a direct and narrow course, relatively few falling for several hundred feet. The catch on the canvas on the 600 foot line showed a seed fall at the rate of 250 winged seeds to the acre. At 850 feet it has increased to 40,000 and at 1100 feet out from the kite 302 seeds fell on a canvas 11 by 15 feet, or at the maximum rate of 80,000 seeds to the acre. The most distant line of canvases, 1600 feet out, showed that the fall had again decreased to 250 to the acre. Some seeds traveled a considerable distance beyond that point as men stationed at the last canvas saw seeds still several feet in the air passing them.

Daily Science News Bulletin, No. 256D.

10. Climate and the Growth of Trees

A. E. Douglass discovered that in the dry climate of Arizona and southern California the rate of growth of trees, indicated by the width of the annual rings, shows close agreement with the amount of rainfall. Some of the big trees (*Sequoia*) still living came into existence four thousand years ago, giving us a unique rainfall record. About 200 measurements of tree-growth were collected by Ellsworth Huntington,[1] who constructed from them a well-known curve of climatic change. The rate of growth of a tree differs at different ages quite apart from climatic factors; a young tree grows more rapidly than an old tree, and there are other difficulties, but a recent publication of the Carnegie Institution of Washington[2] enables us to calibrate the curve of tree-growth.

Discovery, Vol. VI, p. 473.

11. Women's Fingers Work Faster Than Men's

A method of measuring the speed in an individual's fingers has been devised. The test has been applied to 1,020 women applying for work in the shops of an electrical company and the results are described in the forthcoming issue of the *Journal of Personnel Research* by Mildred Hines and Johnson O'Connor.

The equipment used by the experimenters consisted of nothing more than 300 brass pins and a flat metal plate in which 100 holes were drilled part way through. Candidates for work requiring agile

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[1] E. Huntington, *The Climatic Factor as Illustrated in Arid America* (Washington, Carnegie Institution, 1914).

[2] *Quaternary Climates*, papers by L. Claude Jones, Ernst Antevs and Ellsworth Huntington (Washington, Carnegie Institution, July, 1925).

fingers are asked to pick the pins from a tray in which they are piled loosely and to place three pins in each drilled hole in the plate as rapidly as possible. They are instructed to try to pick up the pins three at a time in order to make maximum speed. Individuals vary widely in this test. The fastest finish in less than six minutes and the slowest require from twelve to fifteen minutes.

Since the inauguration of this test seventy-seven new women workers have been assigned to the fine meter or instrument work requiring finger dexterity. Subsequent records show that more than 85 per cent. of these women are successful in the work. The test also showed that women are much better adapted for this work than are men.

The test is said to eliminate much of the guesswork and personal equation factor in the hiring of workers for this type of work.

Daily Science News Bulletin, No. 254C.

12. Hard Roads Save Tires and Gasoline

Poor roads may save road taxes but the tolls they take on tires and in gasoline consumption make the motorist pay heavy taxes in increased fuel consumption and rubber bills, according to Professor S. S. Steinberg of the University of Maryland and assistant director of the National Research Council's Highway Research Board.

Concrete or brick roads save tires according to tests which have been made to determine what kind of road wears out tires the least. In these tests, both cord and balloon tires are used at the inflation recommended by the manufacturers. The car is run up and down selected level stretches of different road types until the vehicle has covered a distance of 500 miles, after which the wear of the tires is determined. Thus far it has been found that tires wear the least on concrete and brick roads, the loss in weight of each tire on these surfaces being about one ounce for a 500 mile run.

"The tire wear on gravel roads is found to be from 2 to 7 times that on concrete or brick, while that on macadam varies from 10 to 50 times the wear on concrete or brick, depending upon the condition of the surface," Professor Steinberg stated.

"The results also prove that front tires wear less than rear tires, the amounts being 50 per cent to 75 per cent less," he continued. "The relatively greater wear on rear tires is due to the bounding and spring of the rear wheels when traveling over rough surfaces. Experiments also show that when we start our cars from rest the

rear wheels exert a downward kick on the pavement, ranging from 100 pounds to as much as one-half a ton. This blow must be resisted by the rear wheels and axle every time the vehicle is started from rest.

"Other investigations are being conducted to determine the relative consumption of gasoline and oil on different types of roads. As a result of these studies, it has been found that the increased consumption of gasoline required to travel by ordinary dirt roads costs the motorist as much as if he had to pay an additional tax of 24 cents a gallon on gasoline. Even good gravel roads impose an additional expenditure equivalent to a 9 cent tax. Compared with the tax imposed by bad roads, the gas tax paid for highway improvement is truly insignificant."

Artificial winds created by large electric fans driving through a tunnel large enough to hold a full sized automobile are used to study the effect of wind resistance. The velocity of these man-made winds varies from 10 to 40 miles an hour, thus producing the same effect as if a car were driven through still air at these speeds. By testing a number of makes of cars, it has been found that when you drive at 35 miles an hour, you are using about 8 horsepower to overcome the wind resistance. If you reduce your speed to 25 miles an hour, you save five horsepower.

Daily Science News Bulletin, No. 261C.

Special Questions

1. How many different things are sampled in this example?
2. What conclusions were reached as a result of the tests?

13. Measuring the Blood Volume

The story I have to relate opens somewhere about the place where the Atlantic becomes the Caribbean Sea, and in the last days of 1921, when, on the deck of the R. M. S. *Victoria* of the Pacific Steam Navigation Company, three of the passengers might have been seen engaged in practices which were, to say the least of it, unusual among the habitués of ocean liners. For Prof. Meakins, then of Edinburgh, now of Montreal, Mr. Doggart, of King's College, Cambridge, and myself were parading the deck, our noses firmly clipped, breathing from rubber bags which we patted and shook the while. By and by we sat down and transferred the ritual of patting the bag to another, but before we ceased from inhaling the "vapour" of the bag a small sample of our blood was taken for analysis. In

other words, the blood volume was being measured. The bag contained oxygen, but with it a certain measured amount of carbon monoxide. The carbon monoxide was in time practically all absorbed in the lung by the blood-stream, through which it was distributed, so that if the amount of carbon monoxide in each cubic centimetre of blood was ascertained (which can be done from the sample), and if that amount be divided into the whole quantity absorbed from the bag, the quotient gives the blood volume. So much by way of description of the method of Haldane and Lorrain Smith as we used it.

JOSEPH BARCROFT, *The Lancet*, 1925, p. 319.

14. Fade-ometers

Will an arc light fade milady's dress as much as the sun? Nearly 11,000 samples of wool, cotton, and silk, dyed by twenty different coöperating laboratories, are being subjected to rigorous exposure to the rays of the summer sun at the United States Bureau of Standards. Two new "fade-ometers" are being used in the tests in which all the conditions prevail of daylight, artificial light, and dampness which dyed fabrics normally encounter.

The results of these exhaustive tests will be published in a complete report which will be of great value to manufacturers in the field of dyes and textiles.

Daily Science News Bulletin, No. 279B.

Special Question

How many different things were sampled? Draw up an exhaustive list of the different problems investigated in this example.

15. The Smoke Problem

Since the days when the shortage of timber for fuel gave rise to the first experiments in the use of coal for domestic purposes, there has been no period during which those who live in towns and cities have ceased to consider ways and means of overcoming the smoke nuisance. As an illustration of the assistance which science can render in this connexion, we may refer to the paper which Dr. J. S. Owens read before the Mathematics and Physics Section of the B. A. (British Association for the Advancement of Science, Toronto Meeting, 1924). The title of the paper was "The Automatic Measurement of Atmospheric Pollution," and it consisted mainly

of a description of a new and simple method of measuring the "smokiness" of the air, together with an account of some of the results obtained by the use of the method.

The degree to which the atmosphere is polluted is usually estimated by means of what is called the "jet dust-counter method." The air which is to be examined is first slightly compressed and saturated with moisture by means of a special damping chamber. It is then blown as a ribbon-shaped jet upon the cover glass of a microscope. The fact that the pressure to which it has been subjected is suddenly released causes the air to expand to its original volume. As it expands it cools and is no longer able to hold all its moisture. The excess moisture is "squeezed out," and condenses as a mist which settles round the particles of dust which the air contains. They are thus in a damp state, and when they strike the cover glass they stick to it, and remain there even after the water has evaporated.

In order to estimate the smokiness of the air it is then necessary, by means of the microscope, to count the particles and to estimate their size. It will be realized that this method can be trusted to give very accurate results and, further, that the microscopic examination can be employed to obtain very detailed information as to the size, shape, colour and general character of the smoke and impurity particles.

It is not, of course, possible to count the particles automatically, although a comparison of the two methods will enable us to express the results of the automatic method in terms of those of the counting method. The automatic recorder is a white filter paper, through a small area of which the air is steadily drawn for a fixed period. The air passes right through, leaving the particles of dust deposited on the paper. This causes a discoloration and gives the paper a definite grey tint. By comparing this with a standard scale of shades the extent to which the air is polluted can be "read off" with remarkable ease. The result so obtained is very accurate. Its only weakness would arise in the case of an atmosphere in which the dust particles were light in colour. For smoky atmospheres in which the dust is black, the results are very satisfactory.

J. Riley in *Discovery*, Vol. V, p. 243.

Special Questions

1. Is sampling involved in both of these methods or only in the first?
2. How was the standard scale of shades, referred to in the last paragraph, probably obtained?

16. The Temperature of the Stratosphere

A temperature of ninety-six degrees below zero Fahrenheit within a little more than eight miles from the earth's surface was recorded during the flight of one of the United States Weather Bureau's sounding balloons sent up last spring from Royal Center, Ind., in a series of flights whose results are just announced. This temperature represented a drop of 166 degrees from that prevailing at the surface.

Forty-four flights were made of balloons, either singly or in groups, attached to a case of recording instruments and a self-opening parachute. Thirty-seven of these instrument cases were found and returned to the Bureau after flights extending in some cases more than 200 miles. Several of these flights exceeded the highest altitude ever reached by any aviator.

The highest was 17,200 meters or about ten and one-third miles, but on this flight the lowest temperature was a little higher than that found two miles lower on the other flight, the minimum being eighty-eight below zero. This was not experienced at the extreme altitude, but two miles or so lower as this balloon entered what weather men call the stratosphere, a relatively warm upper crust of the atmosphere. The stratosphere has several peculiarities. It is warmer than the air below. It is free from clouds as practically no water vapor occurs at these great heights. The winds are less than in the layers just beneath it.

The flights at Royal Center found the bottom of the stratosphere to vary in altitude according to weather conditions on the surface. If the barometer was low on the surface the stratosphere was nearer the earth. If the barometer was high so was the stratosphere. Average height was about eight miles. How high the top of the stratosphere is nobody knows. Sounding balloons have gone up to nineteen miles without going past it.

The balloons used in these Weather Bureau experiments are about forty inches across when inflated. The recording instruments with parachute and wicker case to take up the shock of arrival at the earth's surface weigh less than a pound. The balloons rise until they expand to the bursting point in the rarefied air which at ten miles amounts to about one-tenth the density of surface air.

Most of the balloons came down within fifty miles of the starting point. One was found at Vanceburg, Ky., 213 miles southeast, and another landed at Tillbury, Ont., 200 miles northeast, having crossed Lake Erie en route.

Boston Transcript, Nov. 3, 1926.

17. The Index Number in Economics

Prices never rise and fall alike. They are most chaotic in their changes; some fluctuate violently from day to day; others steadily rise or fall for long periods and some scarcely vary at all. But though some go up and some go down and others change but little, the *general level* of prices is always tending up or down. The problem is to measure these movements of the general level of prices, a problem which is solved by a device called an index number, the invention of an Italian by the name of Carli, in 1750.

An index number is simply a *summary* in some form of the price changes of a selected set of commodities, used as the name suggests, to indicate changes in the level of prices in general. It serves somewhat the same purpose as the water gauge of a boiler, the visible rise or fall of which denotes changes in the invisible level of the water within.

In constructing such an index the first consideration is to select a set of sample commodities, the price changes of which will fairly represent those of commodities as a whole. If all commodities fluctuated alike changes in the prices of a few selected at random would accurately reflect price changes as a whole. But as all commodities do not fluctuate alike and are not all of the same importance as elements of the general system of prices, the value of an index number as a reliable indicator of changes in the general price level will depend in the first place on whether it is based on a carefully chosen representative list of commodities.

Prices of commodities tend to move in groups. And it is the presence of these groups of commodities whose prices advance or fall in harmony, that constitutes a source of danger to index numbers. The prices of raw materials tend to move together and may be distinguished as a class from manufactured goods. Again raw materials may be subdivided into several groups of products with closely related prices, such as minerals, forest, animal and farm products. Manufactured goods may also be divided into two groups which behave quite differently, namely producers' goods and consumers' goods, the former including all articles bought for business use, the latter those purchased directly by consumers. Some of these groups are interrelated and at times move in unison, as in the case of raw materials and the partly finished or finished products made from them. Others differ widely in the degree in which they fluctuate or move in entirely opposite directions. . . .

It is very evident then that an index number based on an undue quantity of any one or two of these groups will not represent prices as a whole and might by being confined to a particular clique grossly misrepresent them, a possibility that those who read index numbers published in the United States purporting to gauge changes in the general level of prices, might do well to bear in mind.

A food index made up for the most part of farm products, animal products and partly finished products produced from them, on account of its susceptibility to seasonal harvest conditions is very apt to give a wrong impression of prices in general.

Just as important as selection of the commodities that go to make up the index is the securing of accurate price quotations; on these the reliability of the index numbers rests. As a rule wholesale market prices are chosen. Representative retail prices are difficult to obtain owing to local variations, though several retail indexes are now published here and abroad. The price quotations for a particular date, such as the first of the week or month may be taken or an average price may be struck from a number of quotations.

HENRY P. SHEARMAN, *Practical Economics* (McGraw-Hill Book Co., Inc.), pp. 260-263.

Special Questions

1. To what extent does this example combine classification and sampling?
2. Is the method of "sampling the samples" employed in this example? Explain your answer.

CHAPTER IV

STATISTICS

For ages men have used *counting* or *simple enumeration* as a method of extending their knowledge of nature. Classification and sampling both presuppose and rest upon counting. But it is only in our own day that the method of counting has been elaborated into the statistical method. So complicated are the details of this method that statistics has become a separate science. Long technical training is required before one can become an expert statistician. But it is not necessary to master all of the technical details of the statistical method either to appreciate its wide scope and significance or to be able to understand its general features and its values and defects.

Broadly speaking, the statistical method consists of four steps, of which *classification* and *enumeration* are the first two, and *ordering the data in series* within each class and *working out exact correlations* between the separate series are the last two. The method is only employed where the data under investigation are so complicated as to make experimentation out of the question but where there is evidence that the facts may be arranged in groups which vary in some ascertainable manner in relation to each other. Hence the preliminary step is to make a careful classification along the lines of the observable variations in which the investigator is chiefly interested. After these classes are made enumerations are obtained for each class. Sometimes these figures are already at hand, since there are numerous governmental bureaus and other agencies which are constantly gathering and tabulating all kinds of statistical material. But frequently weeks and months are spent in making the necessary enumerations. Here, too, sampling may be used to avoid

having to make an exhaustive enumeration where such a task would be almost endless. After the data have been collected in classes the third step is to arrange them in each class in an array or series. This may be regarded as a more detailed classification within each of the original classes. The goal of the method is now within striking distance. It is reached by applying a mathematical formula to determine the exact relation between the separate arrays or series. This fourth step is called correlation.

Karl Pearson's formula for working out correlations is generally applicable and is widely used, although there are other formulæ. It is as follows:

$$r = \frac{\Sigma xy}{n\sigma_x\sigma_y} \qquad \left(\sigma_x = \sqrt{\frac{\Sigma x^2}{n}}, \sigma_y = \sqrt{\frac{\Sigma y^2}{n}}\right)$$

r is the symbol for the *coefficient of correlation,* that is, a pure number indicating the degree of relation between the two variables which are being correlated. It may vary from + 1 to — 1, the former coefficient indicating a perfect *positive* and the latter a perfect *negative* correlation. 0 is the coefficient of correlation when there is absolutely no relation between the two arrays.

x stands for the deviation of any item of the first array from the arithmetic mean of all members of that series and y stands for the deviation of any item of the second array from the arithmetic mean of all members of that series. Σ stands for summation. Hence the numerator of the formula means the sum total of all the products obtained by multiplying each item of the x series with its corresponding item of the y series.

σ_x and σ_y are the respective standard deviations of the two series, and, as the formulæ indicate, they are found by squaring each of the figures in the x and in the y series, adding these squares, dividing the result by the number of items (n) and taking the square root of that. When σ_x and σ_y are determined they are multiplied together and this product is multiplied by the number of items (n). This gives the denominator of the Pearson formula. Dividing the number obtained for the nu-

merator by that obtained for the denominator gives r—the coefficient of correlation.

SIMPLE CORRELATION PROBLEM

Items	Weight	Height	x	y	xy	x^2	y^2
A	152	68	−5	0	0	25	0
B	154	65	−3	−3	9	9	9
C	156	67	−1	−1	1	1	1
D	163	69	6	1	6	36	1
E	160	71	3	3	9	9	9
5	785 / 157	340 / 68			25	80	20

157 = the arithmetic mean for weight.
68 = the arithmetic mean for height.
−5, −3, −1, +6, +3 = the deviations of A, B, C, D, E respectively from the arithmetic mean for weight.
0, −3, −1, +1, +3 = the deviations from the arithmetic mean for height.
$n = 5$, $\Sigma xy = 25$, $\Sigma x^2 = 80$, $\Sigma y^2 = 20$.

$$r = \frac{25}{5\sqrt{\frac{80}{5}}\sqrt{\frac{20}{5}}} = \frac{25}{5\sqrt{16}\sqrt{4}} = \frac{25}{5 \times 4 \times 2} = \frac{25}{40} = .625$$

The reliability of this coefficient of correlation may be determined by the formula for probable error:

$$P.E._r = .675\frac{1-r^2}{\sqrt{n}} = .675\ \frac{1-.3906}{\sqrt{5}} = \frac{.675 \times .6094}{2.236} = \pm .18$$

This would mean that the chances are even that the true correlation for the above simple problem is between .44 and .80. The high probable error in this example is due to the small number of items and proves the necessity for adequate data.

The conclusions reached by the statistical method are frequently best presented in tables or graphs or charts. The student should note such presentations of statistical data in magazines, newspapers and textbooks.

Such sciences as economics, sociology and education have been made possible by the development of the statistical

method, but every science uses this method of reasoning more or less. Yet, valuable though it is, it is frequently abused. "Figures do not lie but liars figure." Statistics favorable to their own position are the favorite resort of propagandists and stock promoters. Two serious defects are basing the conclusion on insufficient data and considering the statistics of only one side of the question.

WHAT TO READ

AIKINS, H. A., *Principles of Logic,* pp. 296-329.
CREIGHTON, J. E., *An Introductory Logic,* Chap. XV.
CUNNINGHAM, H. E., *Textbook of Logic,* Chaps. XXI and XXII.
DOTTERER, R. H., *Beginner's Logic,* Chap. X.
JONES, A. L., *Logic, Inductive and Deductive,* Part II.
ROBINSON, D. S., *The Principles of Reasoning,* Chap. XVIII.
SELLARS, R. W., *The Essentials of Logic,* Chaps. XX and XXII.
WOLF, A., *Essentials of Scientific Method,* Chap. VI.

Some of the best textbooks on the statistical method for beginners are:

DAY, EDMUND E., *Statistical Analysis.*
KARSTEN, KARL G., *Charts and Graphs.*
RIEGEL, R. E., *Elements of Business Statistics.*
THURSTONE, L. L., *The Fundamentals of Statistics.*

WHAT TO DO WITH THE EXAMPLES

1. Analyze each example so as to bring out each of the four steps in the statistical method.
2. State the conclusion (or conclusions) drawn from the statistics or proved by the statistics and give one good reason for thinking that it is valid or invalid, according to which you take it to be.
3. Name the science from which each example is drawn.

1. Climate and Strength

The best athletes live in cool climates. This assertion is made by Guillermo Hoxmark, of the Buenos Aires Weather Bureau, following a study of records in the international Olympic Games. Writing in *Ecology* (Brooklyn, N. Y.), he gives several tables which he believes establish his contention. Says Mr. Hoxmark:

"Several scientists, notably Huntington, have established zones of human energy and also of civilization. The basis of these zones has been the relation which human conditions, such as work in factories, marks in school, health, and activity in business, bear to climatic conditions, especially temperature, humidity, and storm frequency. Many other factors may likewise be used for establishing on a scientific basis the relationships between climate and human energy. One such factor of world-wide interest is the international Olympic Games, the results of which, as measured by the number of points won by various countries, offer a good basis for an investi-

TABLE I

The relation between the mean annual temperatures of 22 nations and the number of points won by each in proportions to population, at the International Olympic Games, Antwerp, 1920. The index numbers (column C) are based on the number of inhabitants per point won, the best taken as 1.0. The nations are arranged in decreasing order of effectiveness.

Rank	Nations	A Points	B Thousands of Inhabitants per Point	C Index Number	D Mean Temperature Cent.
1	Norway	66	40	1.0	3.8
2	Finland	74	46	1.1	3.1
3	Sweden	121.5	49	1.2	5.1
4	Denmark	28	117	2.9	7.2
5	Luxemburg	2	135	3.4	8.9
6	Belgium	40	192	4.8	9.1
7	Switzerland	17	229	5.7	8.6
8	Esthonia	7	250	6.2	4.4
9	South Africa	21	330	8.2	16.4
10	Holland	18	391	9.7	8.7
11	Canada	18	488	12.2	4.6
12	Great Britain	87	544	13.6	9.6
13	United States	201.5	585	14.6	10.6
14	France	63	622	15.5	11.7
15	Italy	54	719	17.9	15.2
16	Australia	5	1,087	27.1	18.2
17	New Zealand	1	1,320	32.9	12.7
18	Greece	2	3,500	87.3	16.3
19	Brazil	6	5,106	127.3	21.7
20	Spain	4	5,337	133.1	13.6
21	Czecho-Slovakia	2	6,798	169.5	8.3
22	Japan	5	15,401	633.5	11.6

gation of the effect of climatic factors on the constitution and activity of man.

"In order to obtain comparable figures whereby the possible effects of climate might be gaged, the first step was to divide the number of inhabitants (census of 1920) by the number of points won in Antwerp and Paris, respectively. This shows how many thousand people there were per point in the various countries. The results appear in column B in Tables I and II for 1920 and 1924 respectively. In these tables the nations that won points in the games have not been placed in the usual order according to the total

TABLE II

Same as Table I, for 26 nations at Paris, France, 1924

Rank	Nations	A Points	B Thousands of Inhabitants per Point	C Index Number	D Mean Temperature Cent.
1	Norway	31.25	85	1.0	3.8
2	Finland	34	99	1.2	3.1
3	Sweden	44.5	134	1.6	5.1
4	Uruguay	10	156	1.9	16.4
5	Denmark	17	193	2.3	7.2
6	Esthonia	7	250	3.0	4.4
7	Holland	19	370	4.4	8.7
8	Belgium	17.75	433	5.1	9.1
9	France	64	613	7.2	11.7
10	Argentine	13	622	7.4	13.5
11	Hungary	8	980	11.6	9.7
12	Great Britain	41.25	1,147	13.5	9.6
13	United States	94	1,254	14.8	10.6
14	Austria	5	1,295	15.3	8.1
15	Switzerland	29.5	1,218	15.6	8.6
16	Italy	25.75	1,508	17.8	15.2
17	Czecho-Slovakia	8	1,699	20.1	8.3
18	Australia	3	1,812	21.4	17.2
19	Haiti	1	2,045	24.2	24.7
20	Portugal	2	3,200	37.8	14.8
21	Jugo-Slavia	4	4,250	50.2	10.7
22	Roumania	4	4,500	53.1	9.3
23	South Africa	1	6,929	81.8	16.4
24	Spain	3	7,116	84.0	13.6
25	Egypt	0.75	17,849	210.8	20.7
26	Poland	0.25	108,640	1,282.9	7.4

number of points (column A), but according to the number of inhabitants needed to win one point (column B).

"Comparing the two tables it is not difficult to observe that the method of calculating points must have been different at Antwerp and Paris. Hence the second step was to calculate the index numbers of column C. For this purpose the smallest number of inhabitants per point, a position which was attained by Norway both at Antwerp and Paris, was called 1.00, and the other countries were ranked accordingly. The index numbers provide an easy way of estimating how far any nation stands from the best result, or 1.00.

"The mean annual temperature of the inhabited parts of each country has been added to Tables I and II in degrees Centigrade. It is quite obvious that low temperature and a low index, which means high average athletic ability, go together. The general agreement between 1920 and 1924 is noteworthy."

Literary Digest, Sept. 12, 1925, p. 24.

Special Questions

1. Apply the Pearson formula to find the coefficient of correlation between index numbers and mean temperatures for the first ten nations in each table. Find the probable error.
2. What bearing do these two coefficients of correlation have on the author's statement that low temperature and high athletic ability go together? Do they prove it or disprove it?

2. A Statistical Study of Popular Morality

An an example of the nature of statistical ethics and as evidence of the value of its results, I give below a statistical study of one phase of popular morality. By popular morality is meant especially the moral opinions of those who have never had any set training in systematic ethics. The purpose is to see if there is among such people a definite scale of moral values in some fairly uniform order of better and worse.

The first step in the study of popular morality is the selection of some definite list of topics to be ranked by the public. This list should be made by the public itself. If the investigator makes his own list, popular opinion may not have a fair chance to express what it has "on its mind."

For the present experiment, the list of topics was made by men and women students at the University of Texas. This list was

made at the very start of a beginning course in ethics in the Spring of 1919. Each student was asked to make a list of the "ten worst practices" among students in the university. Lists of best practices were asked for, but they were disregarded for the present study because they were more difficult to arrange when these names of worst practices were compiled. It was found that sixteen practices stood out as being mentioned most frequently. These practices were put in alphabetical order as follows: Cheating, Dancing, Drinking, Extravagance, Gambling, Gossip, Idleness, Lying, Sabbath Breaking, Selfishness, Sex Irregularity, Smoking, Snobbishness, Stealing, Swearing, Vulgar Talk.

TABLE ON WORSE PRACTICES

1	2	3	4	5	6	7
Practices in Order of Worseness	Ranks by Arithmetical Averages		Arithmetical Averages		Medians	
	M.242	W.292	M.	W.	M.	W.
Sex Irregularity.....	1	1	3.79	2.44	2	1
Stealing.....	2	2	4.05	4.36	3	3
Cheating.....	3	3	4.88	5.09	4	5
Lying.....	4	4	5.13	5.37	5	5
Drinking.....	6	5	7.09	5.88	6	5
Gambling.....	5	6	6.82	6.77	7	6
Vulgar Talk.....	7	7	7.89	7.71	8	8
Sabbath Breaking...	9	8	9.17	8.70	10	9
Swearing.....	8	9	8.42	8.86	8	8
Gossip.....	13	10	10.09	9.59	11	10
Selfishness.....	10	11	9.29	9.85	10	11
Idleness.....	11	12	9.53	10.41	10½	11
Snobbishness.....	12	13	9.97	11.40	11	12
Extravagance.....	14	14	10.75	11.74	11½	12
Smoking.....	15	15	13.46	12.99	15	14
Dancing.....	16	16	14.23	14.51	15	16

This list of worst practices was given to about a thousand students at the University of Texas. For the present study use was made of the answers of 242 men and 292 women who were in the introductory ethics course during the first week of each term from the spring of 1919 to the spring of 1921 inclusive. Students in other courses, in summer school, in advanced ethics courses, and late registrations were all omitted. The introductory ethics courses have

no freshmen, many sophomores, and a moderate number of juniors and seniors.

The instructions read as follows: "After considering all aspects, which of these practices do you consider worst. Place the number 1 opposite this. Mark the next worst 2, and so for all the rest." No further explanations or instructions were given, except that students were asked to give their own opinions. The students were told not to sign their names but to indicate his or her sex. The papers for the two sexes were tabulated separately. It was hoped that having the papers unsigned would give more honest and sincere answers. The students were not timed, but were made to complete the ranking before they left the room.

A. P. Brogan, "A Study in Statistical Ethics," *The International Journal of Ethics*, Vol. XXXIII, pp. 121-125.

Special Questions

1. Use the table on page 95 to explain each of the four steps in statistical reasoning.
2. Apply the Pearson formula to find the coefficient of correlation between the arithmetical averages for the men and the women (columns numbered 4 and 5 in the table).
3. Do the same for the medians (columns numbered 6 and 7 in the table).

3. A Population Problem

The following data have been taken from Volume II of the United States Census Report of the Fourteenth Census. Column 1 is the percentage of native white women between the ages of twenty and forty-four years, who are of foreign and mixed parentage, residing in the twenty largest cities of the United States. Column 2 is the percentage of native white women between the ages of twenty and forty-four who are either married, widowed or divorced.

City	1	2	City	1	2
New York	61	60	Buffalo	54	65
Chicago	64	65	San Francico	54	69
Philadelphia	41	65	Milwaukee	67	65
Detroit	50	74	Washington	19	55
Cleveland	54	70	Newark	53	64
St. Louis	41	67	Cincinnati	38	66
Boston	61	52	New Orlens	27	69
Baltimore	27	60	Minneapdis	61	63
Pittsburgh	47	65	Kansas City	22	75
Los Angeles	33	73	Seattle	41	75

Special Question

Apply the Pearson formula to determine the coefficient of correlation between the two series. Find the probable error.

4. Twenty-Five Million Young Americans Go to School

The great advance along all lines of human endeavor in the United States, at the close of the first quarter of the twentieth century, is particularly reflected in the progress made in education.

A statistical comparison between the educational situation at the end of the nineteenth century and the educational status at the present time reveals the following significant facts: The total population of the United States in 1900 was 75,602,515 with an estimated school population of 21,404,322. In 1924 the total population amounted to 112,078,611, with an estimated school population of 29,345,911. . . . In 1900 the percentage of the school population enrolled in public schools was 72.4; in 1924 it was 82.8.

In the year 1900 the United States had enrolled in its public schools 15,503,110 children, of whom 14,983,859 were in elementary schools and 519,251 in high schools. We were expending for public education at that period the sum of $214,964,618, divided as follows: for capital outlay, $35,450,820; salaries of school employees, $137,687,746; other purposes, $41,826,052.

In 1924 the number of pupils enrolled in the public schools of the country reached 24,288,808, of whom 20,898,930 were in elementary schools and 3,389,878 in secondary schools. We were expending for public education in the United States in 1924 the sum of $1,820,743,936 divided as follows: for capital outlay, $388,469,143; salaries of school employees, $978,064,705; other purposes, $454,210,088.

The average annual salary of all teachers in 1900 was $325; in 1924 it was $1,227. To accommodate the great army of school children 263,280 schoolhouses were required in 1924.

The total number of teachers employed in public schools, elementary and secondary, in 1900, was 423,062; in 1924 the number was 761,308. The value of all school property amounted to $550,069,217 in 1900 and $3,844,780,714 in 1924. In 1900 the percentage of pupils in high schools was 3.3; in 1924 the percentage was 14.0.

The foregoing statistics show that educational progress compared with the growth of population is keeping abreast of the times, and that the rising generation of citizens is being generously cared for.

JOHN J. TIGERT, in the *American Review of Reviews*, Vol. LXXIII, p. 36.

5. Higher Education in America

Registration in 913 colleges, universities, and professional schools of the United States increased nearly six times as rapidly as population in the thirty-four years from 1890 to 1924. From 121,942 in 1890 the number of students in these institutions mounted to 664,266 in 1924, a growth of 445 per cent, as shown by statistics compiled by the Interior Department, Bureau of Education, published in Bulletin, 1925, No. 45. During the same period enrollment in secondary schools increased 951 per cent, about twelve times as rapidly as general population, which increased seventy-eight per cent during this time.

Corresponding increase appears in teaching personnel. The number of professors and teachers in colleges, universities, and professional schools of the country, exclusive of instructors engaged in preparatory departments, jumped during this time from 10,762 to 51,907.

The largest collegiate enrollment in any one State during the year 1923-24 was in New York, where 60,623 men and 28,370 women, a student army of 88,993, were attending colleges, universities, and professional schools. Illinois stands next with a total of 60,462, then Pennsylvania, Ohio, Massachusetts, and California. Five other states had each a collegiate enrollment of 20,000 during the year, and ten other States and the District of Columbia had more than 10,000 students each.

Government Report.

6. Father's Job Influences Son's Ambition

That a father's occupation plays an important part in determining whether or not a clerical worker will stick to his job is the conclusion of Marion A. Bills of the Life Insurance Sales Research Bureau writing in the *Journal of Applied Psychology*.

During the year 1922, 58 clerical workers were hired in a life insurance company's office. Each of the 58 filled out an application blank, stating among other things the occupation of the father. The successful applicants were all hired on the basis of general intelligence and fitness tests.

At the end of 1924 a review of employment records was made to determine how many of the 58 hired in 1922 had remained after two years. It was found that 24 had left the company, practically all of them voluntarily.

In making a study of the causes of turnover among these clerical employees the occupations of the father as given on the application were grouped into seven classes. The classes ranged from that of unskilled labor to that of professional men in about the order in which the average clerk would consider social standing to range.

This analysis revealed that the lower the so-called social standing the father's occupation was, the longer the clerical worker stuck to the job, the higher the parental standing, the sooner the worker left the clerical job.

In explanation the report states that a boy entering upon a clerical job from a skilled laborer's family feels, as he looks forward to possible promotion to higher clerical work paying $3,000 a year, that the future is very bright. On the other hand a boy coming into a clerical job from the family of a salesman, store manager, or professional man, does not look upon such a prospect as being very bright.

Daily Science News Bulletin, No. 236E.

Special Questions

1. Is there a negative or a positive correlation between the social standing of the father's occupation and tenure of job by the son?
2. Are the data in this example adequate to make the conclusion reliable? Explain your answer.

7. Seismograph Records Foretell Storms

The seismograph, the instrument used to record earthquakes, is also a weather forecaster, and its records may be used to foretell storms, according to Robert W. Sayles, of the Harvard University Museum. This is possible, he says in an article on "Superficial Factors in Earthquakes" in the forthcoming issue of *Science*, because the reduced air pressure that comes in advance of a storm causes the earth's crust to rise slightly. This tilting is recorded by the motion of the pendulum of the seismograph, and the direction of the tilt shows the direction from which the storm is approaching.

In the opinion of Mr. Sayles, such variations in air pressure, together with deficiency in rainfall, form the most important of the superficial causes of earthquakes. In particular, he has been studying the earthquakes that shook New England last winter.

"According to the data collected at the Blue Hill Meteorological Observatory at Harvard University," says Mr. Sayles, "we had a deficiency of about 8.1 inches of rainfall during the five months

previous to March 1, 1925. The quake of January 7 was preceded by three months of very dry weather and immediately followed by rain and a normal rainfall for that month. Then during February there was a deficiency again in rainfall, and then the quake of the 28th, which was likewise followed by rain. Just before this quake, on the 26th, we had the lowest barometric pressure recorded in two years, 28.96 inches at Boston. This low pressure area went northeastwardly and when it reached the Saguenay region, where there is a weak place in the crust, the crust gave way and we had the earthquake. It is true that the lowest pressure had passed on to the east before the shock came, but there is often a lagging effect in earth processes. In my opinion the deficiency in rainfall and the very low pressure acting together was the straw that broke the camel's back."

Mr. Sayles points out that when the barometer goes down one inch, a weight of over a million tons is taken off every square mile of the earth's surface, and a deficiency of eight inches of rainfall over New England would be equivalent to taking nearly forty billion tons off the region. Mr. Sayles also points out that an unusual dry spell preceded the Montana trembler of June 27.

Daily Science News Bulletin, No. 236D.

Special Questions

1. Are the statistics adequate to prove Mr. Sayles' conclusion?
2. What bearing would the earthquakes which occur far out in the ocean have on his argument?
3. Make a graph of the weather conditions preceding the New England quakes.

8. Italian Migration as Affected by American Restriction

The excess of births over deaths in Italy is said to be 700,000 annually. What to do with the surplus population has become a real problem. In the last year before the War 296,000 Italians came to the United States. During the War immigration almost ceased, but by 1921 the number of newcomers from Italy had reached 222,000. Then came our first restriction law fixing the maximum at 42,000, followed by the second law further reducing the number to 2,678 annually.

Recent Italian emigration has gone to other countries. Some still cross the ocean. To the Argentine went 33,277 in 1921 and 105,235 in 1923; to Brazil 8,587 in 1921 and 13,574 in 1922. To

Canada went 7,783 in 1923, as compared with half that many two years earlier.

But Italians in far larger numbers found that they could leave the mother country without crossing the ocean. In 1921, 44,782 Italians emigrated to France; and almost five times as many—more than 200,000—went to live there in 1924. Holland and Belgium gained 13,000 as compared with 3,874 in the earlier year.

The total number of Italians leaving Italy rose from 201,291 in 1921 to 364,614 in 1924, an increase of eighty-one per cent.

American Review of Reviews, Vol. LXXIV, p. 88.

Special Questions

1. Make two tables, one for 1921 and one for 1923, setting forth these statistics.
2. Make a graph showing the effect of our restriction laws on Italian emigration.
3. Mention at least one correlation which might be worked out on the basis of these figures.
4. What conclusions do these statistics prove?

9. Crops Affected by Parasites

Crop losses in the United States caused by parasitic organisms such as fungi and bacteria, amount to many millions of dollars annually. Some of these losses are directly traceable to parasites which are carried upon or within seeds, as for instance wheat, oats, barley, corn, rye, beans, etc. It is estimated that all the cereal crops are reduced annually by about three per cent on the average as a result of smuts and other seed borne parasites. The bean crop suffers an average loss of about six per cent, many other crops suffer in proportion.

Through the sale and distribution of infected seed the various parasites have been widely distributed throughout the production areas of the world. Some of these parasites, such as the cereal smuts, are known at the present time to be distributed wherever these crops are grown. It was these facts which led to the passage of the Simmons Bill which became the Plant Quarantine Act in 1912.

C. R. Orton, in the *Literary Digest,* March 27, 1926, p. 23.

10. Suicide and Age

Suicide, in the wage-earning group of the American and Canadian populations, is approximately two and one-half times as frequent among men as among women, we are told by *The Statistical Bulletin* of the Metropolitan Life Insurance Co., (New York). This is shown, we are told, by what has happened among the more than 16,000,000 industrial policy holders of the company. We read:

"The above ratio relates to all ages combined. When the suicide data are studied by age periods, it is shown that the ratio of deaths of males to those of females varies greatly at different periods of life, and that the preponderance of self-murder among males increases perceptibly with advancing age.

"Suicide does not assume much numerical importance until the age 20 is reached. Between 20 and 24, the death-rate for males approximates one and one-half times that for females. Between ages 25 and 34, the ratio is a little more than two to one; during each of the next 10-year periods, it is about four to one; at 55 to 64 years, it approximates five to one; and after age 65, there are about seven times as many suicides among men as among women.

"One age period, namely, 15 to 19 years, stands out in bold relief from all the rest. This is the only time of life in which suicide is more common among females. In 1923, the suicide rate of young women of these ages insured in the Metropolitan's Industrial Department was 4.1 per 100,000—or nearly two and one-half times that for males (1.7).

"The above data relate to white policy holders only. Suicide is much less frequent among colored persons."

Literary Digest, Sept. 12, 1925, p. 25.

Special Questions

1. Make a graph showing the relation of suicides among men to those among women. Use a separate line for each sex.
2. How does the conclusion drawn from the total for all ages combined differ from that drawn by age periods? Which is truest and why?

11. Training Morons

The problem of mental deficiency need not be the great bugaboo we have always thought it, according to Dr. George K. Pratt, assistant to the Medical Director of the National Committee for Mental Hygiene.

Medical science has established, he maintains, that approximately fifty per cent of the cases of feeblemindedness are not congenital. This means that the social menace of the mentally deficient is not half so great as the gloomy family trees of the Jukes and the Kallikaks and such notorious clans have tended to make us believe. Feeblemindedness, when it does not directly originate in the faulty germ plasm received from either father or mother, is due to birth injuries or infectious disease. Spinal meningitis and several of the infantile diseases may result in permanent injury to the brain tissue. The ensuing mental lacks are just as complete as in hereditary cases, but there has been no evidence to prove that they can be transmitted to the next generation.

Less than ten per cent of the whole number of feebleminded are of the potentially vicious class. These, it has been found, are comprised almost entirely of neglected types who have grown up in bad environment. In other words, many of the mentally deficient when properly trained and supervised can be fitted in the community as more or less useful citizens.

The individual of low mental test is especially suited to take over many of the mechanical operations of modern industry. In monotonous and repetitive tasks, often excessively distasteful to workmen of higher caliber, he is of unique value.

The new medical outlook holds that only the vicious ten per cent, and the intellectually lowest types should be segregated. Many of the others should be given institutional training according to their various capacities and taught simple trades. Depending on their personality and ability for adjustment to environment, they should be returned to their communities when they can go to work under such supervision as individual cases require.

Daily Science News Bulletin, No. 256C.

Special Questions

1. Look up the family trees of the Jukes and Kallikaks. (See especially *The Kallikak Family*, by H. H. Goddard and *The Jukes*, by R. L. Dugdale.) What statistical fallacy does this example suggest that the sociologists have committed in basing their conclusions on these family trees?
2. Make a classificatory scheme which will show the results of this investigation.

12. The Missouri Crime Survey

Reporting on the "Missouri Crime Survey" Arthur V. Lashby of the St. Louis Bar Association said it presents the record of ten thousand cases. In addition, it includes a personal study of the methods of conducting trials in the localities where the investigation was made. Sheriffs, prosecuting attorneys, coroners, circuit clerks, circuit judges and others concerned with the administration of criminal laws were interviewed and questionnaires were sent to circuit judges, prosecuting attorneys, sheriffs, and other officials. Some of the facts gathered:

It cost $9,500,000 in 1923 and $10,500,000 in 1924 to run the State's machinery for protection of lives and property of the people.

Losses through operations of criminals in Missouri yearly are $90,000,000.

"In St. Louis during the year of the survey," he said, "there were 13,444 murders and manslaughters, burglaries, robberies, larcenies, embezzlements, frauds, forgeries and automobile thefts committed. During the same period 1420 cases (one in nine) were taken to the prosecutor by the police. The prosecutor refused to issue in 456 of these cases, leaving 961 which were sent to an examining magistrate for preliminary hearing. Exactly three hundred were discharged on preliminary examination, leaving 664 held for action by the grand jury or prosecutor, 40 of these were discharged because of failure of the grand jury or prosecutor to act. Of the 624 going to the trial court, 66 were nolle prossed by the prosecutor; 28 were discharged by the court for various reasons; 110 were tried and acquitted or discharged on numerous grounds—a total of 204—leaving 420 to be sentenced.

"Twenty-six of these were paroled; 20 filed appeals in the Supreme Court; leaving 374 persons actually punished. Obviously a system no more efficient than this showing of 374 punishments out of 13,444 major crimes committed needs revision throughout.

"Conditions in Kansas City are little, if any, better. For murder and manslaughter in St. Louis, only one person out of six is punished; for robbery and burglary, one out of twenty-five; in Kansas City, ten murderers and persons guilty of manslaughter escape to one that is punished; for robbery, twenty-eight escape to one punished; and for burglary, fifty escape to one punished.

"Juries and courts are universally condemned for such failures of justice; 96.5 per cent of all sentences for felony crimes in Missouri

were upon pleas of guilty. In a very great majority of these cases the minimum sentence was pronounced. There is no such thing as life imprisonment in Missouri. Upon good behavior every prisoner is released upon serving seven-twelfths of his sentence.

"Many major crimes are being committed by youths of from seventeen to twenty-four years of age. They are the desperate criminals. Such persons if convicted have their sentence commuted to the reform school, which admits persons, for all classes of serious crimes, of the ages of six to twenty-seven years. The average sentence of inmates of the reformatory is fifty-five months; through parole authorities they are released after an average of eleven months. A surprisingly large number of these parolees commit new crimes while on parole. The bail bond evil in the large cities is most menacing. Collection of forfeited bail bonds is practically unknown. Some professional bondsmen are sponsers for young criminals, and the conclusion is inescapable that these youths are many times forced into new crimes, often attended by the death of the victim, to pay the fee for the last bond."

Boston Transcript, July 14, 1926.

Special Questions

1. Where in this example is the method of sampling implied?
2. How was the investigation carried on? By what means were the data gathered?

13. Farm Profits

The Department of Agriculture's annual survey finds "further improvement in the financial condition of farmers in 1925 over the preceding three years. Reports from 15,330 farmers, in all parts of the country, show an average net return of $1297 for those farms. The average size of the farms was 304 acres, with an average investment of $17,149. Average gross receipts were $2551, consisting of $993 from crop sales, $897 from sales of livestock, $585 from sales of livestock products and $76 from miscellaneous expenses.

"Average current cash expenses totalled $1477, consisting of $386 for hired labor, $242 for feed bought, $69 for fertilizer, $47 for seed, $191 for taxes, $119 for new machinery and tools, and $179 for miscellaneous items.

"Receipts less cash expenses averaged $1074, in addition to which the farmer used home-grown food products valued at an average of $283. The value of fuel and house rent was not reported. On the

other hand, no allowance has been made in the expense items for the labor of the farmer and his family which was estimated by the farmers at an average value of $793.

"The cash balance of $1074 represented all the cash the average farm made available to the owner-operator to pay his living expenses, take care of debts, and make improvements. The farmers reported an increase of $223 in inventory values, which figure added to the cash balance of $1074 make a farm net return of $1297. Out of this amount $225 was paid as interest on indebtedness and $127 was spent for improvements.

"The farm net return of $1297 for 1925 compares with $1205 for 15,103 farms in 1924; $1020 for 16,186 farms in 1923, and $917 for 6094 farms in 1922, both receipts and expenses have increased each year during the four year period."

Government Report.

14. Heart Failure and High Barometer

High barometric readings in the second half of last November have been associated in England with an unusual number of deaths from "heart failure." This fact, brought to public notice by a correspondent of *The British Medical Journal* (London), signing himself "A. O. W.," has drawn from Dr. Percy Stocks, medical officer to the Department of Applied Statistics in the University of London, a communication reported as follows:

"It seemed to him, he writes, that it might be worth while to ascertain whether any statistical evidence for such an association could be obtained. He has therefore correlated the weekly deaths registered in London as due to diseases of the heart and circulatory system with the mean corrected barometric pressures for the same weeks at Greenwich during this period of the year since 1900. Dr. Stocks finds an appreciable relation between deaths from circulatory diseases and the atmospheric pressure. Since a high barometer in November is frequently associated with a low temperature, which is known to increase mortality from circulatory diseases, this might be the real explanation, but to test this possibility the correlations have also been calculated with the mean temperature of the air at Greenwich for the same weeks. When this is done there does appear to be a small but significant relation between heart deaths and atmospheric pressure during November apart from the effect of temperature, a result which seems to confirm the opinion formed by 'A. O. W.' Dr. Stocks adds that there appears to be in the average

year a rapid rise in mortality from circulatory diseases during November, a slight fall during December, and another rise about the New Year, the highest mortality for the year being in January and February."

Literary Digest, March 27, 1926, p. 25.

15. Cash Value of Human Life Investigated

The dollars and cents value of a human being's existence, taking into consideration the investment he represents and his commercial importance to the world, is being investigated by Dr. Louis I. Dublin, statistician of the Metropolitan Insurance Company.

"A man's estimate of the value of his own life may fluctuate widely," said Dr. Dublin today. "At one time, he may be willing to sacrifice all his worldly goods to save his skin, and at another time, as suicide statistics show, he may value his life at less than nothing. But his family and his business associates and the community at large all have a close interest in his existence, and it is sometimes necessary for the courts and insurance companies to set a numerical estimate on the worth of human life.

"The same methods that are used to evaluate manufacturing plants can be applied to the individual. We hope to reckon the cost of installation, running expenses, and a sinking fund against the time of expiration. On the credit side of the account we have such items as current earnings, unpaid services rendered, participation in the upkeep of population, and so forth."

Daily Science News Bulletin, No. 246D.

16. Human Body Grows in Three Spurts

Though a baby, or a small boy, may "grow like a weed," his growth does not go on at a steady, unvarying rate, but in three grand spurts, which overlap each other, making the "growth curve" which scientists plot to measure the rate into a very complex affair. Dr. Charles B. Davenport, of the Carnegie Institution of Washington, told of his studies of this problem before the annual meeting of the National Academy of Sciences.

The first period of maximum growth rate is right at the time of birth. The baby grows fast, as everybody knows, but the rate of growth falls off for several years. Then it starts to speed up again, and in the case of boys, at least, it reaches a climax at about eight years—that embarrassing time when a fellow's knees simply will not stay inside their proper garments. A second slowing-down

follows, and then a second speeding up, the rate of growth reaching its maximum at fifteen—the "all hands and feet" period, when the youth is "shooting out of his shoes."

The three growth-spurts, Dr. Davenport stated, correspond closely with periods of greatest activity of some of the internal glands. The first and second periods of growth correspond with activity on the part of the thyroid and pituitary glands, respectively, whose secretions are known to be growth-promoting. The third cycle, said Dr. Davenport, is a fundamental one, underlying the others, and probably represents some more general growth stimulus exerted from the time of the first existence of life until growth stops altogether.

Daily Science News Bulletin, No. 265C.

Special Questions

1. What things were correlated in the last paragraph?
2. Plot the growth curve implied in this example.

CHAPTER V

MILL'S EXPERIMENTAL METHODS

When an investigator wishes to discover the cause (or the effect) of any event or action in nature he usually employs one or more of the methods described by John Stuart Mill in his *System of Logic.* They were called by him *experimental methods* but logicians now frequently refer to them as *Mill's methods.* He used the word *phenomenon* to refer to the particular event under investigation and he spoke of investigating the cause or the effect of the phenomenon by the methods of (1) *agreement,* (2) *difference,* (3) *the joint method of agreement and difference,* (4) *concomitant variations,* and (5) *residues.* Mill clearly understood that only two principles are used in these five methods.

One principle is the comparing together of instances in all of which the phenomenon under investigation is present. These are called *positive instances.* If the phenomenon is present to the same extent or degree in all of the positive instances the method of agreement is used. If the phenomenon varies in one positive instance as compared with another the method of concomitant variations is applied. This method is also employed when two separate phenomena are shown to be casually related by proving that they vary together.

The other principle is to compare positive instances with instances similar to them but having the phenomenon absent. Hence the latter are called *negative instances.* In the method of difference the negative instance is created out of a positive by removing the circumstance or factor thought to be the cause and thereby removing the phenomenon, providing what is thought to be really is the cause. The rule is: Remove only one circumstance at a time until the real causal factor is discovered. Usually a previous application of the method

of agreement has revealed the invariable antecedents of the phenomenon. This, then, is the method of experiment and it is not applicable except where the material is subject to human control. The joint method of agreement and difference consists in comparing a set of positive instances with a set of negative instances, each set being obtained by observation and enumeration rather than by experiment, in the hope that a single factor common to all the positive and absent from all the negative instances can be discovered. This factor is then held to be the cause.

The method of residues is not really a separate method. When the phenomenon under investigation is highly complex and causes are discovered for separate parts of it, the method of residues simply holds that there must be some additional causal factor at work to cause the *residual* part of the phenomenon. By residual is meant that part of the phenomenon which is left over after the known causes have been isolated and connected with the other parts of the phenomenon.

The joint method and the method of concomitant variations frequently have to give place to the newer method of statistics. Yet both of these methods continue in use for the investigation of phenomena which are not so complicated as to demand the statistical method. Mill was undoubtedly right in regarding the method of difference, which presupposes the method of agreement, as the essence of experimentation. But when the investigator produces a variation, rather than a complete negative instance, the method of concomitant variations is also experimental.

The nerve of the reasoning in each of these methods may be made clearer by the following symbolic scheme, which may be used as a pattern for analyzing the examples.

The Method of Agreement

Positive Instances

No. 1. Circumstances or causal factors *mnx*
No. 2. Circumstances or causal factors *lox*
No. 3. Circumstances or causal factors *ghx*

Since *x* is the only factor common to all the instances, it is the cause of the phenomenon.

The Method of Difference

Positive Instance	Negative Instance
No. 1 or No. 2 or No. 3 from among those used in the method of agreement.	No. 1 or No. 2 or No. 3 with only x removed.
Circumstances or causal factors *mnx* or *lox* or *ghx*	Circumstances or causal factors *mn* or *lo* or *gh*

Since x is present when the phenomenon occurs and absent when the phenomenon does not occur it is the cause.

The Joint Method of Agreement and Difference

Positive Instances	Negative Instances
No. 1. Causal factors *abcd*.	No. 1. Causal factors *aemn*.
No. 2. Causal factors *bkde*.	No. 2. Causal factors *golx*.
No. 3. Causal factors *dgha*.	No. 3. Causal factors *fhij*.

Since d is present in each positive and absent from every negative instance, d is the cause of the phenomenon.

The Method of Concomitant Variations

Normal Positive Instance	Variable Instance
No. 1. Causal factors *abcd*.	No. 1. Causal factors *abcd*, d being changed in some way from what it is in the normal positive instance.

Since the phenomenon varies when d is changed, d is its cause.

The Method of Residues

Complex Instance of Phenomenon

Analysis yields separate constitutents.

No. 1. caused by factor a

No. 2. caused by factor b

No. 3. caused by factor c

No. 4. (Residual part) caused by factor x

Since parts 1, 2 and 3 are caused by factors a, b and c respectively, the residual part of the phenomenon must have a cause, namely, x.

The above scheme is based on the assumption that the problem is to find the *cause* of a given phenomenon. Let the student construct a similar scheme when the problem is to find the *effect*.

WHAT TO READ

Before proceeding with the work of analyzing the examples, the student should study carefully Mill's *System of Logic,* Book III, Chap. VIII, reprinted as Appendix I, to this book.

Read also one or more of the following:

Columbia Associates, *Introduction to Reflective Thinking,* pp. 77-86.
Creighton, J. E., *An Introductory Logic,* pp. 237-264.
Cunningham, H. E., *Textbook of Logic,* Chap. XX.
Gibson, W. R. Boyce, *Problem of Logic,* pp. 395-422.
Hibben, J. G., *Logic, Deductive and Inductive,* Pt. II, Chaps. VI-X.
Jones, A. L., *Logic, Inductive and Deductive,* pp. 90-105.
Joseph, H. W. B., *An Introduction to Logic,* Chap. XX.
McClure, M. T., *An Introduction to Reflective Logic,* pp. 367-377.
Mellone, S. K., *An Introductory Textbook in Logic,* pp. 291-314.
Robinson, D. S., *The Principles of Reasoning,* Chaps. XX and XXI.
Schiller, F. C. S., *Formal Logic,* pp. 263-272.
Sellars, R. W., *The Essentials of Logic,* Chap. XIX.
Westaway, F. W., *Scientific Method,* Chap. XVII.
Wolf, A., *Essentials of Scientific Method,* Chap. V.

WHAT TO DO WITH THE EXAMPLES

1. Analyze each example according to the following pattern:
   (*a*) State what the phenomenon under investigation is and whether the problem is to discover the cause or the effect.
   (*b*) State which of Mill's methods you think was used in the example.
   (*c*) State clearly at least one reason for considering it to be the method you take it to be.
2. Select from the list of examples one of each method for a more detailed analysis according to the form given in the symbolic scheme above.
3. Tell what you think of the reasoning in each example. Is it valid? Could the conclusion be strengthened by using some other method?
4. Name the science or sciences from which each example has been taken.

1. Brain of Literary Genius Found to Be Lightweight

Large brains do not necessarily go with great genius. The brain of Anatole France, which was willed to science, was not only exceedingly small for a well developed old man of 165 pounds but was over a quarter smaller than even the average brain. But Dr. Felix

Renault who examined it states that the brain showed an unusually large number of deep furrows, and that this characteristic, rather than the actual brain weight should be looked upon as proof of highly developed intelligence.

Another example of a small brain in a man of genius, Dr. Renault states, is that of Gambetta, the French statesman, whose brain weighed 1160 grams or 143 grams more than Anatole France's, and was likewise furrowed deeply. Both of these cases suggest that it is the area of the outer surface of the brain and not its weight that has a direct relation to intelligence.

Daily Science News Bulletin, No. 236C.

2. Experiments on the Conditioned Reflex

We have learned much about ourselves of recent years by the application of laboratory apparatus. Take, for example, the conditioned reflex. A dog's mouth, if we ring a bell whenever we feed him, will be found after a time to water whenever we ring the bell, whether we feed him or not. By a very ingenious arrangement worked out in Pavlov's laboratory at Leningrad, the exact quantity of saliva secreted by the dog can be collected and measured, which enables us to measure the strength of the dog's response. This response is said to be conditioned because it obviously depends on the conditions under which the dog has heard the bell ring before. Such responses are distinguished from the unconditioned reflex with which he naturally reacts.

By sounding one note always with food, and another always without, the dog can be made to discriminate musical notes with about ten times the refinement of Mozart or Gerschwin; in fact, the dog's discrimination surpasses our power of producing pure tones for him to choose between. He can also discriminate between shapes, but with much greater difficulty.

Forum, Vol. LXXIV, illustrated section, p. xxvi; reprinted in C. K. Ogden, *The Meaning of Psychology* (Harper and Brothers).

3. Ice-Recession in Fenno-Scandia

The ice recessions in Fenno-Scandia have been studied in detail by Baron de Geer and his pupils by means of the *varve,* or seasonally banded clays. These clays were deposited in fresh water off the receding edge of the ice sheet, one silty and one greasy layer each year, the two together forming a well distinguished annual

layer or *varve;* the varves cover each other as shingles on a roof. Since their thickness varied from year to year, depending upon different summer temperatures, the varves can be recognized from widely separate localities both in the direction of ice recession and at angles to it. By measuring series of varves at a number of localities, plotting graphs and matching them, the rate of ice recession can be determined and the ice edge mapped in detail.

George Grant MacCurdy, *Human Origins,* Vol. I (D. Appleton & Co.), pp. 66*f.*

Special Question

Use this example to show how the statistical method tends to supplant the method of concomitant variations, by showing the extent to which each method was used in making the discovery.

4. Phosphorescence and Electro-Magnetic Fields

It is well known that many phosphorescent bodies when electrified emit a brighter light which usually fades rapidly. Recent experiments in Germany have shown that the same bodies respond only feebly to a magnetic as opposed to an electrical field, although the same phenomena are obtained.

Discovery, Vol. VI, p. 7.

5. Colored Oysters

Recent research shows that the green color of French oysters is due to a pigment present in the food materials. The experiments involved the isolation of the pigment from a quantity of Naviculæ, and it was shown that oysters in a sea-water infusion of the coloring matter took up the color in twenty-four hours.

Discovery, Vol. VI, p. 150.

6. Oxygen Required in Walking

The quantity of oxygen inhaled has a profound effect upon the amount of work that can be performed by the body, which requires it to burn the carbon assimilated in the food. The amount required per minute in walking and running rises as the speed increases, and at high speeds, as in a hundred yards spurt, the amount is ten times that required when sitting or standing still. It appears from experiments that the oxygen inhaled during short periods of exercise it used to oxidize lactic acid and carbohydrates in the blood. But why is more required when the exertions are prolonged? This

additional oxygen must be used in oxidizing other substances in the blood. What these other substances are may be determined by later experiments.

Adapted from *Discovery*, Vol. VI, p. 122.

Special Questions

1. What reason can be given for regarding this as an example of concomitant variations?
2. What reason for treating it as residues?
3. Could it be both methods? Give reason for your answer.

7. Stars and Their Satellites

Observation with the spectroscope of certain stars reveals motions some of which are difficult to explain on the basis of existing knowledge. Professor Joel Stebbins, of the University of Wisconsin, proved that these motions are due to such stars having large companions or planets. By choosing the proper time for light measurements, it is found that among the cases known in advance to be favorable fully one-half of these double systems present eclipses as viewed from the earth. A study of the variation of the light of a star during an eclipse makes it possible to calculate the diameter of both the bright star and its dark or faint companion.

Daily Science News Letter, No. 268A.

8. Measurement of Fear Reactions

That emotion can now be described quantitatively is the assertion of two scientists at Columbia University who have been conducting an interesting series of tests with human subjects in an effort to measure their reaction to fear. While the person under observation is seated in a darkened laboratory with his hands fitted into cuffs, a pistol is suddenly discharged close to his head, or a noisy automobile horn is sounded, or he feels the writhing coils of a large snake unexpectedly placed about his neck. If his eyelashes flicker or the pupils of his eyes dilate the least bit, instruments record the fact, and how much, while other devices register changes in pulse and blood pressure. About the subject's waist is strapped an apparatus which transmits variations in his breathing to a chart. Before the fear stimulus is introduced, the normal pulse, blood pressure and respiration are recorded by means of the instrument. The sudden variations of the needles as the person is disturbed, give the experimenter a clue as to just how much he fears.

Popular Mechanics, Vol. 45, p. 817.

9. Epidemics among Marine Animals

Death of half a million oysters has caused alarm in Japan and may be due to an ocean current straying from its path. Such occurrences, upsetting the balanced plan of nature to which birds and fish adapt themselves, often prove disastrous to man as well as to wild life. In 1925, the warm El Nino current that flows along South America south of the equator wandered far from its usual path, probably due to the weakening of the cool Humboldt current from the Antarctic. Tropical fish invaded the harbors of Chile, and millions of sea-fowls that live along the rainless cliffs starved to death because they were deprived of their usual sources of food. In 1902 Norwegian fishermen experienced a disastrous season. The cod were small, arrived late, and a cod-liver oil famine resulted. The cause was believed to be the failure of the warm current to reach the Arctic seas.

Popular Mechanics, Vol. 46, p. 244.

10. The Value of Intelligence Tests in Industry

A set of psychological tests for taxicab drivers has been devised by Professor A. J. Snow and is now being used to supplement the usual oral examination. Many people question the value of such tests because of the complexity of the human mind. Mr. E. E. Free suggests that their value might be estimated by making a comparison between drivers who have been tested and those who have not. Suppose, for example, ten drivers who have taken the test be compared with ten who have not. We could draw up a list of the characteristics of each man in each set so far as skill in driving is concerned. If we found that all of those who had been tested drove so carefully as to avoid nearly all accidents whereas those who had not been tested were all more reckless, we could conclude that the psychological tests are of high value in selecting taxicab drivers. And the same method might be applied in estimating the value of vocational tests in other fields.

Adapted from *Forum*, Vol. LXXV, illustrated section, July, 1926, p. xxv.

11. The Cause of Goitre

The health of the thyroid gland is of supreme importance. And we know that it depends upon the regular supply to the body of a small but indispensable amount of iodine. This discovery was made

in connection with the hatching and rearing of young fishes in fresh water hatcheries. The water used was unnaturally pure, and it was noted that all of the fish developed goitre. The addition of a little iodine to the water, however, led to their prompt recovery.

Discovery, Vol. VI, p. 31.

12. Sleeping-Sickness in Rabbits

In man there is a simple and innocuous skin disease known as herpes. The fluid from the vesicles in herpes, injected into a rabbit, causes a condition of the brain which cannot be distinguished from sleeping-sickness as it occurs in man.

Idem, Vol. VII, p . 171.

13. The Flavor of Apples

It is a commonplace that the flavor of an apple is improved by keeping. Recent research shows that this is directly traceable to a gradual reduction in the apple's acidity. This decreases at first rapidly and then more slowly, until finally it alters very little over a relatively long period. In apples kept in cold storage, however, the loss of acidity is much slower. If the acidity is too great on putting them into cold storage the apples are practically certain to decompose. Hence, with some kinds, it is better to let them mature naturally for a while before placing in cold storage, a point that has its commercial aspect.

Idem, Vol. VI, p. 245.

14. The Determination of Drift in the Ocean

Locally, tides, winds and the sun's rays have considerable influence upon the course of drift. Another factor besides temperature changes that produces sinking and welling up of the water are variations in the depth of the sea. Vortices are thus produced and since they have a profound effect upon the planktonic organisms they demand careful study.

Since local atmospheric conditions, temperature and wind, have such a profound effect upon drift, it is obvious that the floating bottle method can only give an approximate idea of the drift in a small sea bounded by inhabited coasts, whereon the bottles can land and the questionnaire papers be returned to the investigator. By such means Professors Johannes Schmidt and Giovanni Platania broadly drew the course of the Gulf Stream drift into the Mediterranean Sea. . . . This, however, takes no account of local

variations or the movements at depth below the surface. Further, no reliable results could be gained by the use of this method in an open expanse like the Atlantic where we know from the courses taken by derelict wrecks that the drift outside the few main streams is very erratic indeed. Accordingly instruments have been devised whereby the drift can be determined at any depth. These are based more or less upon the scheme of a weathervane. Let down into a current a vertical vane attached to the side of the instrument keeps it turned to the current whilst other vanes rotating on a shaft record the velocity of the current, the direction of which is ingeniously recorded by balls dropping on to a compass needle so grooved that the balls roll off its end into compartments arranged like the cardinal points of a compass. By calculating the currents due to tidal motion and deducting them from those recorded, the residual current, or drift, is calculable.

T. W. Jones in *Discovery*, Vol. VI, p. 249.

15. Fowls and Vitamin-C

Fowls were kept for some months on a diet containing no Vitamin-C, the vitamin that prevents scurvy. They appeared quite normal and to feel no lack of proper nourishment. In addition on killing them and feeding their livers to guinea-pigs who had developed the usual debility produced by a Vitamin-C deficient diet, these latter recovered and became quite unaffected by the lack of Vitamin-C in their food. It appears possible, therefore, that the fowls' livers contained plenty of Vitamin-C.

Idem, p. 264.

16. Animal Electricity

The man who discovered animal electricity was an Italian, Luigi Galvani, Professor of Anatomy in the University of Bologna. He discovered it accidentally. Galvani noticed that when the living hind legs of a dead frog, which were hanging over a copper hook laid on an iron railing, came in contact with the iron the leg muscles twitched. Galvani at once concluded that these convulsions of the legs were somehow an expression of animal electricity, but Alessandro Volta, his brother professor in the University of Pavia, proved that, in the experiment just quoted, there is indeed electricity developed—not, however, by the living tissues, but at the contact of the two dissimilar metals, the copper hook and the iron railing. When the toes, blown against one of the uprights of the railing, completed the circuit through the legs their muscles twitched.

Galvani nevertheless persevered in his efforts to demonstrate the reality of electricity of animal origin, and succeeded in devising a number of convincing experiments known as "contractions without metals." Quite the most striking of these is to allow the nerve supplying a muscle to lie over the isolated beating heart. At each beat of the heart, the current produced by the heart stimulates the nerve which in its turn causes the muscle to twitch; it is a very curious sight to see the leg of a frog jerking at the exact rhythm of its own heart.

Prof. Fraser Harris in *Discovery*, Vol. VI, p. 226.

17. Whooping Cough Helped by Simple Remedy

That old reliable remedy, sodium bicarbonate, is now recommended in the treatment of whooping cough.

Recent work at the Kingston Avenue and the Kings County Hospital Laboratories, Brooklyn, N. Y., by Drs. J. C. Regan and Alexander Tolstouhov shows that this familiar bane of childhood is accompanied by a condition of severe acidosis which may be counteracted by small repeated dosages of simple alkaline salts, such as sodium bicarbonate, calcium carbonate or magnesium oxide. In patients treated by this method early or late in the disease, a cure is induced.

Blood examination shows that the inorganic phosphorous content during whooping cough is lowered and the hydrogen ion concentration is greatly increased. The alkaline doses bring about a rapid return of the phosphorus to its normal proportion in the content of the blood and counteract the acidity. These chemical changes in the blood are accompanied by pronounced improvement in the patients so that vomiting ceased, according to Dr. Regan, on an average within one week and whooping within two weeks, with occasional exceptions. The patients generally showed corresponding improvement and increase in weight. It has been suggested that the characteristic symptom of vomiting in whooping cough is a compensating mechanism of the body to eliminate the excess acid.

Daily Science News Bulletin, No. 267C.

18. Tuberculosis among Apes

A series of experiments, continuing the efforts of years to find an effective vaccine against tuberculosis, are being carried out in tropical West Africa on the manlike apes. . . .

Human conditions were reproduced as far as possible in the ape

colony. Fifty-nine chimpanzees lived under similar conditions of exposure. Nineteen were vaccinated, twenty were infected with virulent tuberculosis germs and twenty were kept unvaccinated as control animals whereby to judge the rest.

Of the nineteen vaccinated, eleven died of various causes but never showed any sign of tuberculosis even at death, and the other eight are now in good health. Of the twenty unvaccinated animals kept as controls, nineteen died of tuberculosis and the other of an acute infection of another kind. Of the twenty animals infected with virulent tuberculosis, nineteen died of the disease and the other of intestinal trouble. Thus out of fifty-nine apes, only eight are now alive and all of these had been vaccinated.

Daily Science News Bulletin, No. 239A.

19. Blood Volume and Temperature

It was remarkable enough that the curve of our blood volumes ran almost parallel to that of mean temperature of our cabins—rising as we approached the tropical heat of Central America, falling as we entered the cooler "Humboldt current" on the West Coast of South America. Were we right in supposing that temperature was the cause, not something coincident with the vascular changes which interested us? The matter was not difficult to test subsequently at home. Two colleagues, Drs. Davies and Fetter, offered themselves for the purpose. Each lived for three days in the glass room which forms part of the equipment of the Cambridge Physiological Laboratory. The season was one of snow; the temperature of the glass room was maintained at 90-95 F. day and night. The blood volume was measured independently by Dr. Davies, Prof. Meakins, and myself. The changes were just such as had taken place at sea and now clearly were due to rise in temperature. The physiological significance is clear enough; large cutaneous vascular areas are opened up in response to the heat, the blood to fill them must come from elsewhere, and as "elsewhere" may have need of it, it is desirable to have a volume of blood commensurate with the size of the vascular bed.

Joseph Barcroft, *The Lancet,* Feb. 14, 1925, p. 320.

20. The Body's Hidden Blood Depot

It was not merely the amount of water in circulation which was influenced by temperature. . . . It was the total amount of hæmoglobin. The mystery was: "Whence came this outpouring of hæmo-

globin"? It was not credible that the bone-marrow could have provided the body with new corpuscles at the rate required. Moreover, there was no evidence of increase of immature corpuscles in circulation. . . .

The question then was forced upon us: Has the body any considerable but hidden store of hæmoglobin which can be drawn upon in case of emergency? . . . In searching for a locality which might fulfill such a condition one naturally seeks in the first instance for some place where the red blood corpuscles are outside the circulatory system—some backwater outside the arteries, capillaries, and veins. There is only one such place of any considerable size in the body—that place is the spleen.

Idem, p. 321.

Special Questions

1. In what sense can the preceding example be said to have set the problem in this?
2. Are the methods of reasoning used in the two examples the same?

21. The Function of Corti's Fibres

Helmholtz's theory of Corti's fibres . . . received its substantial confirmation from the subsequent observations of V. Hensen. On the free surface of the bodies of Crustacea, connected with the auditory nerves, rows of little hairy filaments of varying lengths and thicknesses are found, which to some extent are the analogues of Corti's fibres. Hensen saw these hairs vibrate when sounds were excited, and when different notes were struck different hairs were set in vibration.

Ernst Mach, *Popular Scientific Lectures* (Open Court Publishing Co.), p. 29.

22. A Vaccine for Spotted Fever

A vaccine has been made from the ground bodies of disease-carrying cattle ticks that gives immunity to Rocky Mountain spotted fever, transmitted by the same parasites. Drs. R. R. Spencer and R. R. Parker of the U. S. Public Health Service have successfully vaccinated rabbits, guinea pigs, monkeys and human beings against this much dreaded fatal infection of the western cattle range. Up to the present time thirty-four persons have been vaccinated against the infection and none of these has succumbed to the disease. . . . Guinea pigs treated with the serum were immune to the disease for

eight months, which was as far as the tests extended. Vaccinated monkeys remained immune and others that had not been treated died. A cattle dipper in affected area had been vaccinated before he was bitten by infected ticks that he picked by hand off of the cattle. He developed a mild form of the disease but was never in danger. He recovered completely while four other persons infected died within ten days.

Daily Science News Bulletin, No. 240A.

23. The Source of Value

To what do economic goods owe their value? For the sake of illustration, let us suppose some outdoor loving American, lured perhaps by aggressive Canadian advertising, is spending his vacation canoeing on one of Ontario's wild and beautiful lakes. Since it is a hot summer day, he is thirsty, and so dips his cup in the lake or better still, in camping vernacular, "shoots the bottle"; that is, he lowers a stoppered bottle weighted with a stone to the bottom of the lake, jerks out the stopper and draws up a bottle of cool water to quench his thirst. Let us suppose, again, a traveler on the Sahara Desert with only a meager supply of water left in his canteen, which he has been hoarding with jealous care, arrives at an oasis owned by an Arab sheik and bargains for a supply of fresh water. In both cases the commodity quenches thirst and has utility; in the second case it possesses also value. What is the cause of the value of the water in the second case? The illustration suggests the answer: scarcity. . . . Value then is born of a union of utility and scarcity. Neither one of these alone gives rise to value, for however useful a commodity is, its supply must be limited to have value; and however scarce a commodity is, it must be wanted to possess value. In all values everywhere these two elements are always present. They are the two universal causes of the values of economic goods.

H. P. Shearman, *Practical Economics* (McGraw-Hill Book Co.), pp. 230*f*.

Special Questions

1. Does this illustrate the method of difference or the joint method?
2. Give examples of other commodities where both scarcity and utility are present and other examples where one is present without the other.

24. Blood Cells Tell When Operation Needed

Miss Viola Brewer's research has given doctors a new method of sizing up mastoid infection and determining the need for an operation.

Miss Brewer has succeeded in taming the eosinophiles, those white corpuscles in the blood which become reddish on contact with the stain employed in making blood counts. Her discovery came about in connection with her laboratory work, in which blood counts were a part of the daily routine. The results of daily tests in mastoid infections centered her attention on the circumstance that subsiding infection is always indicated by a change in the character of the patient's blood test.

Through careful study and comparison, Miss Brewer demonstrated that severe infection causes disappearance of the eosinophile corpuscles in the blood of the patient. With improved conditions these corpuscles reappear in normal abundance. Frequent tests in individual cases showed that there was uniformity in the disappearance and reappearance of the eosinophiles. Close study showed that the changes were in exact harmony with the bedside record of clinical symptoms, including pain, swelling and temperature. In temperatures ranging from 98 to 100 the percentage of eosinophiles was at its maximum. By pursuing the comparisons the technician became convinced that the corpuscles could be made valuable aids to physicians on watch.

Daily Science News Bulletin, No. 243D.

Special Question

Is this concomitant variations or difference or both? Explain your answer. (See Robinson's *Principles of Reasoning,* pp. 276*f.*)

25. Polarized Light Speeds Growth of Bacteria

Germs grow faster when they get their light arranged in a certain way, according to the results of the investigations of two Indian scientists, S. S. Ghatnagar and R. B. Lal, of the University of the Punjab, Lahore, who have just reported to the scientific journal *Nature.*

The two experimenters took cultures of the germs of typhoid fever and cholera, and exposed one set to ordinary light, while the second set was placed under a beam of polarized light. Polarized light differs from ordinary illumination in that the fronts of the

light waves are all arranged in the same direction, while in ordinary light they criss-cross at all angles. The germs seemed to thrive much better on polarized than on ordinary light.

Daily Science News Bulletin, No. 259D.

26. Spider Bite Treated with Convalescent Serum

Spider bites are added to the list of afflictions that can be treated with a specific serum, Dr. Emil Bogan has reported to the American Medical Association.

While serious poisoning from spiders is not so common as is popularly believed, there is a species inhabiting the southern half of the United States that causes acute pain and sometimes death. It is known variously as the "shoe-button spider," the "hourglass spider" and the "black widow," the last being a reference to its pleasant conjugal habit of devouring its mate.

About half of the reported cases attributed to the work of the black widow occurred in California, said Dr. Bogan, and those received in the Los Angeles General Hospital were treated first with sedatives to relieve the intense agony from which the patients were suffering. Very little is known of the antibody formation to spider venom but experimental work has indicated that one bite confers immunity. This possibility led to the suggestion that some specific serum treatment might be helpful. Accordingly a sample of blood was obtained from a man who had recovered from a severe poisonous spider bite and injected intramuscularly into a patient who had just entered the hospital in great agony.

Since this patient improved after the treatment, the same procedure was followed in other cases with a much quicker abatement of pain than would have been expected without it, said Dr. Bogan.

"The results," he declared, "while not conclusive, are sufficiently encouraging to warrant the continuation of the use of convalescent serum in every case that is admitted following a poisonous spider bite, and a supply of convalescent serum is now kept at the hospital for this purpose."

Daily Science News Bulletin, No. 276B.

27. Growth of Hair Ruled by Gland

Reporting on a series of seven experiments, Hsi Chun Chang, of the physiology laboratory of the University of Chicago, states that the thyroid gland has a specific effect upon the growth of hair.

Mr. Chang said that the removal of the thyroid gland of laboratory animals retards the growth of the hair. After feeding them a suitable amount of desiccated thyroid he found that the hair grew normally once more. Undernourished animals also experienced retardation of hair growth, which was accelerated by the feeding of a thyroid preparation.

Thyroid atrophy is also known to be induced by undernutrition, Mr. Chang reported. The determination of the real cause of the hair reaction, therefore, is difficult. However, he added, the experimental discovery that thyroid feeding improves the hair growth of undernourished animals, in spite of further decreases in body weight, is a significant proof of the influence of the thyroid gland on hair growth. Further experiments on the study of the constituent of the thyroid gland responsible for the hair reaction are now in progress, with the hope of determining whether the hair reaction can be used as a functional test for the thyroid gland.

Daily Science News Bulletin, No. 269B.

Special Question

Do you think that the difficulty here is what logicians call the plurality of causes? (See Creighton's *Introductory Logic,* p. 244, or Robinson's *Principles of Reasoning,* pp. 260*f*.)

28. The Transparency of New-Laid Eggs

By holding an egg between the eye and a 50 candle power metal filament lamp (or a similar light), it is possible to tell its age to within twelve hours. A newly-laid egg, less than an hour old, appears uniformly transparent, except for a few dark spots here and there due to inequalities in the shell. Twelve hours afterwards, however, lighter patches appear, and the egg looks more or less blotchy near the "ends" (the "top" and "bottom"). These patches are more or less blurred in outline. As time goes on they increase in definition and number and are more easily seen from twenty-four hours of age onwards. Recent research shows these patches to be due to the hygroscopicity, or affinity for water, of certain parts of the shell. Water is absorbed and transparent patches are formed. Other parts of the shell, on the other hand, lose water by evaporation, and so become more opaque. The formation of the blotches is prevented by keeping the eggs in an atmosphere saturated with moisture.

Discovery, Vol. VII, p. 87.

29. The Winter Sap of Evergreens

Why do the leaves of evergreens hang on all winter long, when by rights they should be frozen and drop off? According to researches of Dr. Floyd W. Gail, of the University of Idaho, they stick because in winter their sap becomes too thick to freeze.

Dr. Gail gathered leaves from pine trees and from broad-leaved evergreen shrubs once every month through three years, crushed out the sap and tested it for its freezing point. He found that during the summer when the weather is warm and the sap flows freely it is relatively thin and could be frozen easily if there were any frost to freeze it. But as fall comes the starch in the leaves is converted into sugars and oil, changing the sap from a thin and watery fluid into a sort of sirupy emulsion, very difficult to freeze. He found that the greatest density of the sap was reached during late January and February, when the most severe freezing weather occurs.

Science Supplement, Vol. LXIV, p. xii.

Special Question

Does the first sentence of the second paragraph imply a use of the method of sampling? Why or why not?

30. Proof That Thorianite Is Radio-Active

Thorianite is one of the few minerals that are radio-active. I took a small handful of crystals and inadvertently placed them on a table with my camera, which had a plate ready in position for exposure. The crystals and camera remained on the table all night, and I found when I developed the photo with a picture on it that there were rays of light across the picture. I guessed the cause, and then put another plate in to test my theory. I got the same result, proving conclusively that thorianite was radio-active.

T. Bowyer-Bower in *Discovery*, Vol. V, p. 24.

31. Science Knows How Fast Fairy Rings Grow

Scientists have measured the rate of growth of "fairy rings." Sometimes these circles of mushrooms will advance as much as thirteen inches beyond where they were the year before.

It is now generally conceded, according to J. Ramsbottom, British mycologist, that these "fairy rings" are due to the yearly under-

ground growth of the fungus mycelium or roots rather than to the dissemination of spores from a constantly increasing radius. For centuries fairy rings have been described in song and folk lore, and everything from fairy feet and dragon's breath to moles and thunder have been ascribed as their causes.

The rate at which the mycelium extends outward varies with the climate and variety of mushroom. One ring which has been under observation for many years was found to have an average increase of about five and a half inches annually. It has been calculated that some rings in California are in the neighborhood of 251 years old. One ring on Salisbury Plain has been described as over 50 feet in diameter.

Daily Science News Bulletin, No. 262A.

32. Local Immunity

Dr. A. Besredka, a young Russian scientist, has discovered an entirely new principle in bacteriology which has been named "local immunity." According to this principle, disease-causing organisms are frequently quite impotent to do harm away from their usual habitat. Anthrax, for example, is always an affliction of the skin and surface tissues. Dr. Besredka devised means for planting cultures of the germs deep in the muscular tissue, in the lungs and elsewhere in the bodies of guinea pigs. Aside from a little inflammation, probably due to the mechanical irritation of the instruments used, the animals showed no signs of harm from the usually deadly organisms. Less serious skin infections, like those caused by staphylococcus, the germ of boils, were shown to act in the same way.

Dr. Besredka's discoveries have already become of practical importance in medicine. After showing that susceptibility to bacterial infection was local, the Russian scientist also showed that immunity could be conferred more effectively by serums and other preventive means if applied equally directly to the regions usually attacked by the disease. Since typhoid fever is a disease of the digestive tract, Paris physicians are now following Dr. Besredka's principle, and administering antityphoid serum through the mouth rather than by means of injection into the arm. Dr. Besredka claims that when administered in the ordinary way the serum gets no chance to act until the blood has carried it from the muscles of the arm into the intestinal tract.

Daily Science News Bulletin, No. 237C.

33. Pharaoh's Locusts Led Double Lives

The swarming locusts of the Sudan, which are probably the same as those that made Pharaoh's life miserable for him in the days of the bondage of Israel, are veritable Jekyll-and-Hyde insects, according to a report just received from Dr. H. Bennett Johnston of the Wollcome Tropical Research Laboratories at Khartoum. Part of the time they hop around peaceably as solitary and unorganized grasshoppers, doing nobody any very great harm. Then, when conditions become right, they start breeding faster and faster, and also assume a radically changed appearance, so that even skilled naturalists have long listed them as entirely different species. In this phase they form the vast, devouring swarms that have been synonymous with terror and famine for ages.

Dr. Johnston has succeeded in producing the change from one form to another under experimental conditions. By subjecting the solitary hoppers to severe overcrowding in his brooding cages he obtained offspring of the swarming type, and by giving individuals of the swarming type plenty of room he bred generations of the common solitary insects.

He points out that his discovery will probably have economic significance, due to the fact that if the solitary grasshopper breedings are kept under constant and consistent attack it will reduce the likelihood of the rapid breeding that must precede swarm formation.

Daily Science News Bulletin, No. 280D.

Special Questions

1. Is this concomitant variations or difference? Give a reason for your answer.
2. How many experiments are implied in the second paragraph?

34. Bad Temper a Relic of Disease

Dr. G. M. Stratton studied the expressions of anger and fear in college students. "There is a difference between the data on students who have always been normally healthy and those who have a disease record," he stated. "Individuals who have had disease show a somewhat more intense emotional reaction in anger situations than those who have not had disease. The intensity of fear responses, however, does not seem to be different in the two classes of individuals. Men who have disease histories appear to be thrown further from normal and into readiness for somewhat more intense

anger than do women who have had a similar history. And the importance of the various diseases is probably not entirely the same with men and women, since influenza affects men but does not appear to affect women."

Literary Digest, March 6, 1926, p. 22.

Special Questions

1. State at least four different problems investigated by Dr. Stratton and show how each might have been dealt with by the joint method of agreement and difference.
2. Show how the same problems could be investigated by the statistical method with a view to bringing out the close connection between the joint method and the statistical method.
3. Could it be said that the joint method passes into the statistical method when a large number of individuals are studied instead of only a few?

35. The Cause of Hardness or Softness in Lead Pencils

Amorphous graphite, principally from Mexico, and flake graphite, mostly from Ceylon and Madagascar, mixed with clay from which all grit has been removed are the ingredients of lead pencils. Clay is the binder which holds the fine, slippery particles of graphite into a solid mass. It makes possible the different degrees of hardness; the more clay the harder the lead, the more graphite the softer the lead. By carefully varying the proportions, seventeen degrees of hardness are made possible.

Literary Digest, Feb. 13, 1926, p. 86.

36. Sleepy Sickness Carried by Changeable Germ

The tiny organism that causes sleepy sickness, or *encephalitis lethargica,* and has mystified scientists since the first appearance of the disease in Vienna during the world war, has at last been definitely tagged and identified by Miss Alice C. Evans, of the U. S. Hygienic Laboratory. The organism belongs to the streptococcus group of bacteria. It varies so greatly in size that it can pass through the finest filter devised by science, and yet it grows so large at other times that it can easily be seen with the ordinary microscope.

The disease is not the same as the African "sleeping sickness," that is caused by an organism carried by the tsetse fly. *Encephalitis lethargica* has been thought by some scientists to be due to the same organism that causes influenza, because it has followed influenza epidemics.

Miss Evans obtained the sample streptococci, with which she experimented, from the brain of a patient who had died of sleepy sickness at St. Elizabeth's Hospital for the Insane at Washington. The organisms were cultivated in test tubes and used to inoculate rabbits. The animals contracted the same disease, and after death the identical organisms were found in great quantities in the rabbit's brains. The disease was given to other rabbits by means of germs recovered from the brains of the ones that had died; this was continued until a succession of seventeen rabbits had been killed by the descendants of the original streptococci taken from the brain of the human case. . . .

Daily Science News Bulletin, No. 242A. (Cf. *Discovery,* Vol. V, p. 144.)

37. The Nature of Colloidal Solutions

If a powerful beam of light is passed through a solution which is not colloidal, and which is truly free from dust and air-bubbles (not an easy thing to insure), the path of the beam is not visible from the side. But if such a beam is passed through a colloidal solution, the path of the beam is visible laterally as an illuminated streak, usually of bluish colour. This is because the minute particles in the colloidal solution scatter a certain amount of the light which falls upon them, some of which enters the eye of the observer looking sideways at the beam. This is a very sensitive test for the presence of suspended particles (colloids); one drop of milk in half a pint of water shows the effect strongly. The illuminated beam is called the "Tyndall cone" after the famous physicist of that name, although Faraday had previously observed and investigated the phenomenon with his colloidal solutions of gold.

Discovery, Vol. V, pp. 34 *f.*

38. Piezo-Electricity

It has long been known that certain crystals, when submitted to pressure or strain, possessed the property of generating a small but steady current of electricity so to speak on their own account. This form of electricity is known as piezo-electricity, and, though the actual flow of current is very small, it is in the case of a large crystal capable of working several high resistance telephones. The fluctuations in the current vary directly with the stresses applied to the crystal, and it is possible that this property will find a commercial application in connection with amplifiers for use in wireless.

Idem, p. 185.

39. Blue and Red Flowers Colored with the Same Dye

It makes no difference whether a flower is red or blue, its hue is due to the same fundamental substance. Its redness or blueness depends on the chemical nature of the plant sap. For example, deep red dahlias and blue cornflowers contain the same pigment but the sap of the dahlias is acid and that of the cornflowers is alkaline; and this makes all the difference. Intermediate shades depend on the degrees of acidity or alkalinity.

The name of this versatile plant pigment or dye is "anthocyanin," according to Prof. R. Robinson, well-known English physiological chemist, who told of investigations in this branch of plant physiology before the Royal Institution of Great Britain. This strange-looking word is made up of two simple Greek roots, which translate into "flower-blue," which is exactly descriptive of one of its phases.

There are really many distinct anthocyanins, Prof. Robinson explained, though chemically they are practically identical. By analysis they can all be shown to be derived from three fundamental substances, which are closely related to each other. . . .

Daily Science News Bulletin, No. 257F.

40. Weird Disease Turns Teeth Purple

A weird and rare disease, that turns the teeth purple and makes sunlight on the skin unbearable, was discussed by Prof. J. Barcroft, well-known English physiologist, in a lecture before the Royal Institution. The affliction is so rare that there are only three known cases in England at the present time, but it is of especial interest to physiological and medical science because the purple substance, porphyrin, is closely allied to the red material, hemoglobin, that gives blood its color. Subtracting its iron and albumen from hemoglobin by appropriate chemical means leaves porphyrin.

Although porphyrin is rare as a normal coloring in adult animals, it is the commonest pigment found in egg shells of birds. Almost all the colors of birds' eggs, from the blue of the robin's to the homely brown of the hen's, contain this strange coloring matter.

No one knows yet why the bodies of these unfortunate patients should be manufacturing the wrong pigment, Prof. Barcroft said, but the fact remains that it is constantly being formed and deposited in their bones, teeth and skin. Porphyrin reacts strongly to the "invisible light," or ultra-violet part of the solar spectrum, so that

the victims of this mysterious ailment have to wear gloves constantly, and if they go out of doors in the daytime must put on heavy veils.

Daily Science News Bulletin, No. 259C.

41. The Cause of Dengue Fever

Sixty-four men who have submitted themselves as subjects to artificial inoculation by mosquito bites have enabled army medical authorities to determine the source of the tropical disease known as dengue fever. . . .

As a result of the experiments it has been conclusively shown by Drs. J. F. Siler, H. W. Hall and A. P. Hitchens in a report in the Proceedings of the Society of Experimental Biology and Medicine, that dengue fever is transmitted by a mosquito known as *Aedes egypti.* The investigators found that uninfected mosquitoes can pick up the virus causing the disease from the patient only during the first three days after its outbreak and from six to eighteen hours before it appears.

Once the mosquito becomes infected by biting a dengue patient, it was ascertained that it is capable of infecting humans during the rest of its existence. The infection, however, is not passed on as an inheritance to the next generation of insects. When the mosquito becomes infected for the first time nearly two weeks must elapse before it can inflict the disease on a human being. The period of incubation in man was found to be much shorter, sometimes taking place in less than a week.

Daily Science News Bulletin, No. 259A.

Special Questions

1. List the different discoveries made by the investigators.
2. Was the same method probably used in making each discovery?

42. Measures Giant Strength of Big Apes' Muscles

A chimpanzee is more than four times as strong as a man of the same weight, according to the results of experiments by Prof. John E. Bauman of Muhlenberg College. Prof. Bauman induced several of the big apes in zoos in various parts of the country to pull a rope attached to a strength-measuring apparatus, and then had a number of football players at Augustana College, South Dakota, try their strength on the same instrument.

It was no easy task, Prof. Bauman states, to induce the chimps

to make the pull. The best method seemed to be to get an ape of a mean disposition, who would haul at the rope in a fit of rage. Good-natured monkeys would merely play with it. One termagant named Suzette, at the New York Zoölogical Park, gave a good, hearty, two-handed pull that registered 1260 pounds, over half a ton. Later on she made another, without putting her full strength into it, marking up 905 pounds. Boma, a good-natured male, the largest chimpanzee in captivity, made a one-handed pull of 847 pounds. Johanna, a female at the Philadelphia Zoölogical Garden, got into an almost impossibly awkward position for her one-handed pull, yet registered 378 pounds, which is better than the average man can do with both hands under the best conditions.

The seven football players tested by Prof. Bauman were all husky farm lads, most of them of Viking ancestry. Yet their best efforts fell far short of those of the apes. One-handed pulls did not in any case react more than 210 pounds, and the best of the two-handed pulls fell a little short of 500.

Since the larger of the men weighed a good deal more than the chimpanzees, Prof. Bauman reduced his figures to a weight-for-weight basis, and then determined the ratio of ape-strength to man-strength. These figures showed that the gentle Suzette was from two and one-half to four and three-quarters as strong as South Dakota's finest, while Boma's strength outranked the human athletes' by between three and four-fifths and four and three-quarters to one.

Daily Science News Bulletin, No. 256C.

Special Questions

1. Is this an illustration of a causal relation? Explain your answer.
2. If so, which of Mill's methods does it exemplify?
3. Is the conclusion reached positive or negative?

43. The Alternation of Glacial and Inter-Glacial Periods

Wegener discusses the astronomical causes of the alternation of glacial and inter-glacial periods. He gives a table showing the variation in the total amount of solar radiation received by the northern and southern hemispheres respectively during the last 650,000 years. This variation is due to variations in the ecliptic—the angle made by the plane of the equator with the plane of the earth's elliptic course around the sun—and in the eccentricity of this elliptic course itself. Sometimes the two sets of variations reinforce

each other in their effect upon the amount of the sun's radiation, sometimes they tend to cancel out.

The whole matter is susceptible of mathematical calculation, and this has been performed by Professor Milankovitch, of Belgrade, from whose results the table is constructed.

JULIAN HUXLEY, in *Discovery*, Vol. VI, p. 367.

44. The Effect of Ice on the Sun's Rays

With an ice-lens in the polar regions Dr. Scoresby has often concentrated the sun's rays so as to make them burn wood, fire gunpowder, and melt lead; thus proving that the heating power is retained by the rays, even after they have passed through so cold a substance. By rendering the rays of the electric lamp parallel, and then sending them through a lens of ice, we obtain all the effects which Dr. Scoresby obtained with the rays of the sun.

JOHN TYNDALL, *The Forms of Water* (D. Appleton & Co.), p. 37.

45. The Relation of Time and Intensity in Natural Phenomena

In the production of natural phenomena two things always come into play, the *intensity* of the acting force, and the *time* during which it acts. Make the intensity great, and the time small, and you have sudden convulsion; but precisely the same apparent effect may be produced by making the intensity small, and the time great. This truth is strikingly illustrated by the Alpine ice-falls and crevasses; and many geological phenomena, which at first sight suggest violent convulsion, may be really produced in the selfsame almost imperceptible way.

Idem, p. 99.

46. The Relation of Climate to Race

Old writers fancied (and it was a very natural idea) that the direct effect of climate, or rather of land, sea, and air, and the sum total of physical conditions varied man from man, and changed race to race. But experience refutes this. The English immigrant lives in the same climate as the Australian or Tasmanian, but he has not become like those races; nor will a thousand years, in most respects, make him like them. The Papuan and the Malay, as Mr. Wallace finds, live now, and have lived for ages, side by side in the same tropical regions, with every sort of diversity. . . . Climate is clearly

not *the* force that makes nations, for it does not always make them, and they are often made without it.

WALTER BAGEHOT, *Physics and Politics* (D. Appleton & Co.), p. 84 *f.*

47. The Color of Sweet-Peas

We know that the color of a sweet-pea is not caused by a single color-bearing factor, but by the coöperation of two factors. For if two varieties of sweet-peas both having white flowers are crossed, the resulting generation is all purple. The two white peas are apparently similar, differing only in the shape of the pollen grains. Each kind will breed true for generations but when crossed they produce the several varieties of purples, reds, and whites.

G. C. BOURNE, in his Spencer Lecture for 1909 (Oxford University Press), p. 31*f.*; slightly modified.

48. The Effect of Environment on Animals

Borneo closely resembles New Guinea, not only in its vast size and freedom from volcanoes, but in its variety of geological structure, its uniformity of climate, and the general aspect of the forest vegetation that clothes its surface. The Moluccas are the counterpart of the Philippines in their volcanic structure, their extreme fertility, their luxuriant forests, and their frequent earthquakes; and Bali, with the east end of Java, has a climate almost as arid as that of Timor. Yet between these corresponding groups of islands, constructed, as it were, after the same pattern, subjected to the same climate, and bathed by the same oceans, there exists the greatest possible contrast, when we compare their animal productions. Nowhere does the ancient doctrine—that different countries are due to corresponding physical differences or similarities in the countries themselves—meet with so direct and palpable a contradiction. Borneo and New Guinea, as alike physically as two distinct countries can be, are zoölogically as wide as the poles asunder; while Australia with its dry winds, its open plains, its stony deserts, and its temperate climate, yet produces birds and quadrupeds which are closely related to those inhabiting the hot, damp, luxuriant forests which everywhere clothe the plains and mountains of New Guinea.

ALFRED R. WALLACE, quoted by Walter Bagehot in *Physics and Politics* (D. Appleton & Co.), p. 85*f.*

49. The Cause of Spinescence

Spinescence, which is a very prevalent characteristic of desert plants, doubtless serves very adequately the purpose of defense, although it may also admit of another explanation, for spines tend to diminish as humidity increases and increase where it diminishes. But the number of grazing animals against whose depredations the spines are thought to be effective diminish in direct proportion to the increase in aridity and hence where spinescence is most highly developed. This would seem to weigh against the belief that such structures are the result of adaptations for defense.

R. S. Lull. *Organic Evolution* (copyright, 1917, by the Macmillan Co.; reprinted by permission), p. 398.

50. Magnetic Attraction

Let us consider a magnetized bar of steel by the side of a second unmagnetized bar, in all other respects the same. The second bar gives no indication of the presence of iron filings; the first attracts them. Also, when the iron filings are absent, we must think of the magnetized bar as in a different condition from that of the unmagnetized. For, that the mere presence of the iron filings does not induce the phenomenon of attraction is proved by the second unmagnetized bar.

Ernst Mach. *Popular Scientific Lectures* (Open Court Publishing Co.), p. 243.

CHAPTER VI

ANALOGY AND CIRCUMSTANTIAL EVIDENCE

Like the method of agreement, analogy operates with resemblances or similarities. But there is a fundamental difference between these two methods. For whereas agreement is applied in determining the cause of a specific event or phenomenon, analogy is used when the investigator wishes to ascertain whether objects or relations, which resemble each other in definite ways which are known, will also resemble each other in a certain other respect, known only to hold of one of the objects or relations in question.

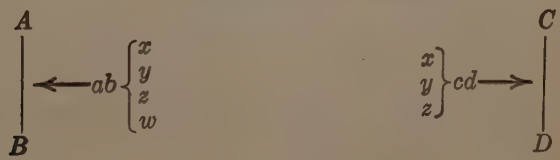
Symbolically this may be represented as follows:

(1) *Analogy between Objects*

$$A\begin{cases} a \\ b \\ c \\ d \end{cases} \qquad\qquad B\begin{cases} a \\ b \\ c \end{cases}$$

Since A and B resemble each other in having the characters abc, and A is known to have the character d, it is probable that B will also have the character d.

(2) *Analogy between Relations*



Since ab, the relation between A and B, resembles cd, the relation between C and D, in having the characters xyz, and since ab is known to have the character w, it is probable that cd will also have the character w.

Mathematical proportion is one kind of analogy between relations. If $A : B :: C : D$ and A weighs six pounds, B twelve and C ten, it follows that D will weigh twenty pounds. But since there are many other similarities between relations besides quantitative ones, mathematical analogy between relations is not the only kind.

Analogies are not always instruments of discovery. Many analogies used by scientists are for the purpose of making some difficult matter clear to those who lack the technical knowledge essential to a complete understanding of it. Sometimes the only way a scientist can impart to the general reader a knowledge of an important discovery he has made is by using an analogy. In such analogies a conclusion may not be drawn but a list of resemblances is always given.

Both in discovery and in exposition the method of analogy is useful to all scientists. It really underlies the method of classification in that objects are classified together which are alike. Hence all sciences which use classification make more or less use of analogy. Then, too, this method is valuable in the quest for good tentative hypotheses.

Circumstantial evidence, important in legal science as well as in many of the natural sciences, is essentially reasoning by analogy. To take an example from criminal law, because a certain person, X, resembles the hypothetical person who committed a murder in having in his possession property of the murdered person, in having been seen near where the crime took place at about the time it was committed, and in possessing a weapon like the one with which the person was killed, it is highly probable that X is the murderer. Resembling the hypothetical person in so many respects X must resemble him in having committed the deed—must be identical with him. Such reasoning is essentially analogical.

Many analogies are fallacious. Four important defects are: (1) basing the conclusion on too few resemblances, (2) failure to weigh the resemblances so as to avoid superficial ones, (3) failure to take account of important differences which might invalidate the conclusion, and (4) *false analogy* or

drawing a conclusion from resemblances when its opposite is just as or even more likely to be true.

WHAT TO READ

Bode, B. H., *An Outline of Logic,* pp. 161-197 (especially good on the relation of analogy to classification and circumstantial evidence).
Columbia Associates, *Introduction to Reflective Thinking,* pp. 119*f.*
Creighton, J. E., *Introductory Logic,* Chap. XVIII.
Gibson, W. R. Boyce, *The Problem of Logic,* Chap. XLII.
Hastings, *Encyclopedia of Religion and Ethics,* article "Analogy."
Hibben, J. G., *Logic, Deductive and Inductive,* Pt. II, Chap XIII.
Joseph, H. W. B., *An Introduction to Logic,* Chap. XXIV.
McClure, M. T., *An Introduction to the Logic of Reflection,* pp. 232*f.*
Mill, J. S., *System of Logic,* Book III, Chap. XX.
Robinson, D. S., *The Principles of Reasoning,* Chap. XXIII.
Welton and Monahan, *An Intermediate Logic,* Chap. XXIX.
Westaway, F. W., *Scientific Method,* Chap. XXII.
Wigmore, J. H., *The Principles of Judicial Proof.*
Wolf, A., *Essentials of Scientific Method,* pp. 24*f.*

WHAT TO DO WITH THE EXAMPLES

1. Tell what kind of an analogy each example is: (*a*) whether between objects or relations, (*b*) whether it emphasizes the aspect of discovery or is primarily intended to clarify exposition.
2. List all of the resemblances and state the conclusion, if one is implied.
3. Tell whether the example contains any of the four defects mentioned in the last paragraph of the exposition above.
4. Name the science from which the example is taken.

1. The Relation of Facts and Abstract Ideas

I have sometimes thought of the phenomenon called "total reflexion" in Optics as a good symbol of the relation between abstract ideas and concrete realities, as pragmatism conceives it. Hold a tumbler of water a little above your eyes and look up through the water at its surface—or better still look similarly through the flat wall of an aquarium. You will then see an extraordinarily brilliant reflected image say of a candle-flame, or any other clear object, situated on the opposite side of the vessel. No ray, under these circumstances gets beyond the water's surface: every ray is totally reflected back into the depths again. Now let the water represent the world of sensible facts, and let the air above it represent the world

of abstract ideas. Both worlds are real, of course, and interact; but they interact only at their boundary, and the *locus* of everything that lives, and happens to us, so far as full experience goes, is the water. We are like fishes swimming in the sea of sense, bounded above by the superior element, but unable to breathe it pure or penetrate it. We get our oxygen from it, however, we touch it incessantly, now in this part, now in that, and every time we touch it, we turn back into the water with our course re-determined and re-energized. The abstract ideas of which the air consists are indispensable for life, but irrespirable by themselves, as it were, and only active in their re-directing function.

William James, *Pragmatism* (Longmans, Green & Co.), pp. 127*f*.

It is interesting to compare this analogy with one used by Epictetus near the end of the first century A.D.:

The soul is like a vase filled with water; while the semblances of things fall like rays upon its surface. If the water is moved, the ray will seem to be moved likewise, though it is in reality without motion. When, therefore, any one is seized with a giddiness in his head, it is not the arts and virtues that are bewildered, but the mind in which they lie; when this recovers its composure, so will they likewise.

Special Questions

1. Do you think that Epictetus was explaining the same relation that James was explaining in his analogy?
2. How can James's analogy be regarded as an improvement over that of Epictetus?

2. An Analogy from Plato

You know, I said, that the dyers, when they want to dye wool for making the true sea-purple, begin by selecting their white colour first; this they prepare and dress with much care and pains, in order that the white ground may take the purple hue in full perfection. The dyeing then proceeds; and whatever is dyed in this manner becomes a fast colour, and no washing either with lyes or without them can take away the bloom. But when the ground has not been duly prepared you will have noticed how poor is the look either of purple or of any other colour?

Yes, he said, I know that they have a washed-out and ridiculous appearance.

Then now, I said, you will understand what our object was in selecting our soldiers, and educating them in music and gymnastic; we were contriving influences which would prepare them to take the dye of the laws in perfection, and the colour of their opinion about dangers and of every other opinion was to be indelibly fixed by their nurture and training, and not to be washed away by such potent lyes as pleasure—mightier agent far in washing the soul than any soda or lye; or by sorrow, fear, and desire, which are the mightiest of all other solvents. And this sort of universal saving power of true opinion in conformity with law about real and false dangers, I call and maintain to be courage, unless you disagree.

The Dialogues of Plato, 4th ed., Vol. III, Bk. IV of the "Republic," Jowett's translation (Clarendon Press).

Special Question

Does the first paragraph of this example seem to you to involve the use of one of Mill's methods? If so, which one?

3. Are College Men Wanted?

If the man recently out of college or technical school is questioning, as seems to be the case, whether he wants Big Business as a life mate, likewise is Big Business questioning whether it has done well to take unto itself the college man. These questionings on both sides are more acutely to the fore during the first year or two of the union than ever afterward. If the union has not been dissolved at the end of this time, it settles down into a round of mutual adjustments that work for the fair average of content we find in the domestic ménage once the turmoil of its beginning has subsided.

As a representative of Big Business, I have often been responsible for this match. I have "sold" the company to the young man graduating from college, university, or technical school; I have "sold" the young man to the company. Very often I have looked back rather ruefully on my work, as a clergyman must who has performed the ceremony on an occasion whose felicitous promise is far from fulfilled. But at any rate, standing, as I did, for a number of years as a sort of buffer between the two, with Big Business pouring into one ear its objections to the college man, and the college man pouring his grievances into the other, I have learned something of the state of mind of each. It is doubtful whether here, as in marriage, to push the analogy a step further, there is more serious

or widespread maladjustment than ever existed before, but parties to unhappy unions of all sorts now seek more generally to escape them. They are more vocal.

A. W. Armstrong in *Atlantic Monthly*, Vol. 138, p. 12.

Special Question

What do you think the author means by the expression "to push the analogy a step further"?

4. Corti's Fibres

Two pianos stand here by the side of each other, both tuned alike. We will employ the first for exciting the notes, while we will allow the second to respond; after having first pressed upon the loud pedal, so as to render all the strings capable of motion.

Every harmony struck with vigor on the first piano is distinctly repeated on the second. To prove that it is the same strings that are sounded in both pianos, we repeat the experiment in a slightly changed form. We let go the loud pedal of the second piano and pressing on the keys *c e g* of that instrument vigorously strike the harmony *c e g* on the first piano. The harmony *c e g* is now also sounded on the second piano. But if we press only on one key *g* of one piano, while we strike *c e g* on the other, only *g* will be sounded on the second. It is thus always the like strings of the two pianos that excite each other.

The piano can reproduce any sound that is composed of its musical notes. It will reproduce for example, very distinctly, a vowel sound that is sung into it. And in truth physics has proved that the vowels may be regarded as composed of simple musical notes.

You see that by the exciting of definite tones in the air quite definite motions are set up with mechanical necessity in the piano. The idea might be made use of for the performance of some pretty pieces of wizardry. Imagine a box in which is a stretched string of definite pitch. This is thrown into motion as often as its note is sung or whistled. Now it would not be a very difficult task to construct a box which would open at the whistling of a certain melody. Sesame! and the bolts fall. Truly, we should have here a veritable puzzle-lock. . . .

Let us look again at our piano, or what will do just as well, at some other contrivance of the same character. What does this instrument do? Plainly, it decomposes, it analyses every agglomera-

tion of sounds set up in the air into its individual component parts, each tone being taken up by a different string; it performs a real spectral analysis of sound. A person completely deaf, with the help of a piano, simply by touching the strings or examining their vibrations with a microscope, might investigate the sonorous motion of the air, and pick out the separate tones excited in it.

The ear has the same capacity as this piano. The ear performs for the mind what the piano performs for a person who is deaf. The mind without the ear is deaf. But a deaf person, with the piano, does hear after a fashion, though much less vividly, and more clumsily, than with the ear. The ear, thus, also decomposes sound into its component tonal parts. I shall now not be deceived, I think, if I assume that you already have a presentiment of what the function of Corti's fibres is. We can make the matter very plain to ourselves. We will use the one piano for exciting the sounds, and we shall imagine the second one in the ear of the observer in the place of Corti's fibres, which is a model of such an instrument. To every string of the piano in the ear we will suppose a special fibre of the auditory nerve attached, so that this fibre and this alone, is irritated when the string is thrown into vibration. If we strike now an accord on the external piano, for every tone of that accord a definite string of the internal piano will sound and as many different nervous fibres will be irritated as there are notes in the accord. The simultaneous sense-impressions due to different notes can thus be preserved unmingled and be separated by the attention. It is the same as with the five fingers of the hand. With each finger I can touch something different. Now the ear has three thousand such fingers, and each one is designed for the touching of a different tone. Our ear is a puzzle-lock of the kind mentioned. It opens at the magic melody of a sound. But it is a stupendously ingenious lock. Not only one tone, but every tone makes it open; but each one differently. To each tone it replies with a different sensation.

Ernst Mach, *Popular Scientific Lectures*, (Open Court Publishing Co.), pp. 25*f*.

5. Radiation

Nothing better of its kind can be imagined than Sir Oliver Lodge's essay on "Radiation." It deals first with the atom as the ultimate source of all radiation. The atoms of the chemical elements, conceived by Dalton, have given place, in the light of more recent research, to a simpler view of the constitution of matter, that based

on the electron and proton, the natural and fundamental units of negative and positive electric charge. These, the particles or atoms of electricity, are the bricks with which nature builds. In their varied groupings and arrangements they enter into the constitution of matter in all its variations, and are sufficient to account for its properties. The physical universe consists of these two kinds of things, and also of one other, "the radiation due to sudden movements and rearrangements among those charged particles," the electrons and protons. "It is by this third or apparently supplementary, subsidiary, or accidental, consequence of the spasmodic behaviour of the other two that we know anything about them."

Sir Oliver Lodge explains that "the most usual view of radiation is that it consists of waves in a connecting medium, commonly called 'the ether' "; but says, impartially, that some do not care to use the term "ether," and are not sure of the nature of the waves, although no one doubts the fact of radiation.

He describes the spectrum of radiation. The visible spectrum has been extended, and although the eye cannot observe them, there are radiations which can be detected by other means. Thus the ultra-violet rays, X-rays and gamma rays from radium are radiations having a shorter wave length than that of violet light. Similarly, the infra-red rays are waves of greater length than those of red light. Moreover, following from the work of Clerk-Maxwell, who first saw that light could be regarded as an electro-magnetic radiation, this extended spectrum may be linked on to the whole range of "ether" waves, generated by purely electrical means, such as are used in wireless. These also, it is now well known, travel with the velocity of light. . . .

It must be mentioned that the whole range, from the shortest known gamma rays to the longest electrical waves, can be shown in a chart, without a gap, all intervening wave lengths having been experimentally detected or generated. . . .

Discovery, Volume VI, p. 374.

Special Question

Just what constitutes the analogy between the visible spectrum and the spectrum of radiation? Visible spectrum suggests the colors of the rainbow. Does Sir Oliver Lodge mean that the spectrum of radiation resembles the rainbow, or does he mean something else by the visible spectrum?

6. Contact Catalysis and the Mechanism of Chemical Reactions

It was known to Berzelius, a famous Swedish chemist, nearly a century ago, that the presence of relatively small quantities of certain substances alters the speed of chemical changes, the substances themselves undergoing no permanent change. Berzelius proposed the name "catalysis" . . . for this sort of action, while the agent employed was called a "catalyst."

Ostwald compares the action of a catalyst with the influence of oil on the wheels of a machine. The similarity is indeed quite marked. To illustrate, the catalyst is unchanged in weight and composition at the end of the action; the lubricating oil is not burned up or changed chemically. Moreover, the catalyst speeds up the chemical change very much as oil lessens friction and accelerates the working of the wheels of a machine. It is also true that the catalyst does not change the nature of the product any more than does the oil added to a machine. As expressed by Holmyard, "If oil be added to a machine making paper bags, the machine will continue to make paper bags and not packets of cigarettes."

As a rule a chemical change is not started by a catalyst; it merely affects the rate or speed of change. Positive catalysts may be compared with lubricating oil on a machine, while negative catalysts may be likened to the action of grit in a machine. Thus, hydrogen peroxide, which is familiar in the average household, has a tendency to break down into water and oxygen; so in order to lessen this tendency a small quantity of acetanilide is added as a negative catalyst.

Water functions as a positive catalyst in many chemical reactions.[1] Perfectly dry carbon, for example, will not burn in perfectly dry oxygen; but when a trace of moisture is introduced, the action proceeds vigorously, producing carbon dioxide.

It is wonderful to observe the effect of catalysts, or to watch them at their work. It is of interest to note that the organic catalysts, known as enzymes, work independently—one splits starch, another splits proteins, and still another splits fats. Indeed, catalysts remind one of the different branches of a great labor union, a member of one branch refusing to do the work of a member of a different branch.

WILLIAM FOSTER in *Discovery*, Vol. VII, p. 233.

[1] It is doubtful if *any* chemical reaction will take place in complete absence of moisture.

Special Question

There are two analogies in this example. What is the second one? Is it like the first?

7. The Astronomy of the Atom

Let us consider the atom of hydrogen with its nucleus and one electron. There will be a force of attraction between the two, proportional to the product of their charges and inversely proportional to the square of the distance between them; in fact, the law of attraction is of exactly the same form as that between a planet and the sun. The electron will thus fall toward the nucleus, unless it already possesses a velocity in some other direction, just as the earth would fall into the sun if its velocity in its orbit were suddenly checked. We must consider then that the electron describes an orbit around its nucleus just as a planet describes an orbit around the sun, and since the law of attraction is the same in the two cases, this orbit will also be an ellipse, or in special cases a circle. Thus we may speak of the astronomy of the atom.

Discovery, Vol. V, p. 64.

8. The Decline of the Franc

The currency of a nation holds the same place in relation to the nation as that of a share of stock to the company by which it is issued. In other words, currency is the stock certificate of a nation and a sensitive barometer of the financial condition and position of the country.

This summer (1926) we have splendid examples of how high stocks can go and how low a currency can fall. General Motors corporation common stock is reflecting on the New York Stock Exchange the best year in the corporation's history. It is doing so by selling at the highest price its shares ever brought.

On the other hand, France was never in worse financial straits than she is at present. And the franc this summer has touched lowest levels in all time.

General Motors stock is traded on the New York Stock Exchange and it is there that it is making its new records. The franc is traded for American dollars in "La Corbeille" (the basket), a sort of stock exchange in Paris. . . .

Living costs in France have increased tremendously since the war. Billions of francs must be raised by the government to meet its debts

to other countries. These conditions make the franc worth less money just as the share of stock in a company is cheaper when the company is heavily in debt and far from prosperous.

FRED E. RIPLEY in a syndicated news article.

9. Two Types of History

Thanks to the subdivision of history into "Ancient," "Mediæval" and "Modern"—an incredibly jejune and meaningless scheme, which has, however, entirely dominated our historical thinking—we have failed to perceive the true position in the general history of higher mankind, of the little part-world which has developed on West-European soil from the time of the German-Roman Empire, to judge of its relative importance and above all to estimate its direction. . . . To toy with phrases such as "the Greek Middle Ages" or "Germanic antiquity" does not in the least help us to form a clear and inwardly-convincing picture in which China and Mexico, the empire of Axum and that of the Sassanids have their proper places. And the expedient of shifting the initial point of "modern history" from the Crusades to the Renaissance, or from the Renaissance to the beginning of the 19th Century, only goes to show that the scheme *per se* is regarded as unshakably sound. . . .

The most appropriate designation for this current West-European scheme of history, in which the great Cultures are made to follow orbits round *us* as the presumed centre of all world-happenings is the *Ptolemaic system* of history. The system that is put forward in this work in place of it I regard as the *Copernican discovery* in the historical sphere, in that it admits no sort of privileged position to the Classical or the Western Culture as against the Cultures of India, Babylon, China, Egypt, the Arabs, Mexico—separate worlds of dynamic being which in point of mass count for just as much in the general picture of history as the Classical, while frequently surpassing it in point of spiritual greatness and soaring power.

OSWALD SPENGLER, *The Decline of the West,* translation by C. F. Atkinson (copyright, 1926, by Alfred A. Knopf, Inc.), pp. 17, 18.

10. Physical and Mental Training

Everybody who has trained himself to physical exercises discovers the extent of his muscular powers to a nicety. When he begins to walk, to row, to use dumbbells, or to run, he finds to his great delight that his thews strengthen, and his endurance of fatigue

increases day after day. So long as he is a novice, he perhaps flatters himself there is hardly an assignable limit to the education of his muscles; but the daily gain is soon discovered to diminish, and at last it vanishes altogether. His maximum performance becomes a rigidly determinate quantity. He learns to an inch, how high or how far he can jump, when he has attained the highest state of training. He learns to half a pound, the force he can exert on the dynamometer, by compressing it. He can strike a blow against the machine used to measure impact, and drive its index to a certain graduation, but no further. So it is in running, in rowing, in walking, and in every other form of physical exertion. There is a definite limit to the muscular powers of every man, which he cannot by any education or exertion overpass.

This is precisely analogous to the experience that every student has had of the working of his mental powers. The eager boy, when he first goes to school and confronts intellectual difficulties, is astonished at his progress. He glories in his newly-developed mental grip and growing capacity for application, and, it may be, fondly believes it to be within his reach to become one of the heroes who have left their mark upon the history of the world. The years go by; he competes in the examinations of schools and colleges, over and over again with his fellows, and soon finds his place among them. He knows he can beat such and such of his competitors; that there are some with whom he runs on equal terms, and others whose intellectual feats he cannot even approach. Probably his vanity still continues to tempt him, by whispering in a new strain. It tells him that classics, mathematics, and other subjects taught in universities, are mere scholastic specialties, and no test of the more valuable intellectual powers. It reminds him of numerous instances of persons who had been unsuccessful in the competitions of youth, but who had shown powers in after-life that made them the foremost men of their age. Accordingly, with newly furbished hopes, and with all the ambition of twenty-two years of age, he leaves his University and enters a larger field of competition. The same kind of experience awaits him here that he has already gone through. Opportunities occur—they occur to every man—and he finds himself incapable of grasping them. He tries, and is tried in many things. In a few years more, unless he is incurably blinded by self-conceit, he learns precisely of what performances he is capable, and what other enterprises lie beyond his compass. When he reaches mature life, he is confident only within certain limits, and knows, or ought

to know, himself just as he is probably judged of by the world, with all his unmistakable weakness and all his undeniable strength. He is no longer tormented into hopeless efforts by the fallacious promptings of overweening vanity, but he limits his undertakings to matters below the level of his reach, and finds true moral repose in an honest conviction that he is engaged in as much good work as his nature has rendered him capable of performing.

FRANCIS GALTON, *Hereditary Genius* (D. Appleton & Co.), p. 15*f*.

11. Chalk-Mill Eoliths

(An eolith is an intentionally chipped or utilized stone, shaped or employed during the Tertiary Epoch. An artifact is an object produced by human art.)

That natural processes such as torrential action, pressure of overlying beds, change of temperature, and wave action might suffice to produce eoliths, was thought to have been demonstrated by the appearance of flints that had passed through a chalk mill. The first observation of this kind was made by Laville, preparator at the *Ecole des Mines* (Paris), at a cement factory southeast of Mantes, near Paris.

In extracting chalk from the quarry, most of the flint nodules are cast aside; some, however, pass unnoticed by the workmen and are carried with the chalk to the factory. These, together with a certain amount of clay, are emptied into circular basins or diluters. In their passage through the basins, the flint nodules receive thousands of knocks, some mutual, some from the iron teeth. At the end of twenty-nine hours the machinery is stopped, and the nodules are removed, washed, and piled up to await their ultimate use as a by-product. It was in one of these piles that Laville's discovery was made. Later, he revisited the place in company with Boule, Cartailhac, and Obermaier.

According to Boule, the flints that had passed through the machine had all the characters of the ancient river gravels. Most of them had become rounded pebbles, but some were chipped in a manner to resemble true artifacts. He and his companions were able in a few minutes to make a "superb collection including the most characteristic forms of eoliths, hammerstones, scrapers, spokeshaves," etc.

Boule does not pretend that all eoliths have a natural origin more or less analogous to those made by machinery. He does claim "that

it is often impossible to distinguish between intentional rudimentary chipping and that due to natural causes." In his opinion, the artificial dynamics of the cement factory are comparable in every respect with the dynamic action of a natural torrent.

After a careful comparison of machine-made eoliths from both Mantes and Sassnitz with eoliths from Belgium, Hahne's conclusions are as follows: (1) the chalk-mill flints are all scratched and otherwise marked by the iron teeth of the mill; (2) the sides of all the larger pieces are bedecked with scars from blows that were not properly placed to remove a flake; (3) almost every piece shows more or less of the original chalky crust of the nodule; (4) anything like a systematic chipping of an edge or margin is never found, except for a very short stretch, where one would expect it to be carried along the entire margin; this is quite different from the long retouched margins of most eoliths; (5) the same edge is often rechipped first on one side and then on the other, absolutely without meaning or purpose (the "reverse working" of true eoliths is quite another thing); (6) in the mill product, coarse chipping alternates with fine retouches along the margin, while on the eoliths there is a regular and orderly sequence of chipping; (7) the repeated rechipping of the same edge, while others are left untouched, does not occur in machine-made eoliths; (8) the chief difference is between the haphazard and meaningless on the one hand, and the purposeful on the other. The most prominent and easily breakable parts suffer most in passing through the mill. They are often retained intact, or only slightly altered to serve as a handhold on the eolith and there is a logical relationship between the worked and unworked portions..

George Grant MacCurdy, *Human Origins*, Vol. I (D. Appleton & Co.), pp. 90-92.

Special Question

What defect does Hahne's observation reveal in Boule's analogical inference?

12. Human Nature and War

Of the Four Horsemen described in the Apocalypse, science gives us high hope that at least two can be unhorsed. By our increasing medical knowledge we are gradually ridding the world of Pestilence. And there is reason to believe that science will rid the world of Famine. But with regard to War there are many who assert that science offers no hope whatever; that it indeed closes the door of hope and leaves us to despair.

For war, it is said, springs from human nature; and it will continue as long as our unchanging human nature lasts.

Those who declare that war comes from human nature, and that human nature does not change, have weighty evidence in their favor. Wars have occurred since the remotest time of history. Wars doubtless were waged long before history began. Fighting reaches still farther back, into the animal world, where it is frequent and widespread. Thus all the momentum of our animal and human inheritance would seem to carry us fatally forward along the ways of war. Humanity seems pugnacious in its very nerve and muscle; man, it would appear, is born to battle as the sparks fly upward. Human nature, through all the ages, reveals certain constant qualities, and whatever may be the strong desire for another order of life, so it would seem, no other order may be expected.

And yet institutions based upon permanent traits of human character have been torn down and swept away, and without destroying or even weakening a single one of these lasting traits of our nature.

Let us go back, not to the cave-man, but to comparatively recent times in America, Asia and Africa, where it was customary to sacrifice living men to the gods. Sometimes these sacrifices were of the worshipper's own children; for by offering something still more precious than war prisoners—more precious both to the worshipper and the god—it was thought that the divine wrath could be appeased.

We may imagine the opposition when it was proposed to do away with this ghastly institution. "What!" it must have been said, "Do you expect us to surrender our very religion—to refuse to our god the rarest, the most valued things we have?" But in spite of such misgivings, human sacrifice was abolished from all lands, and without altering a single one of the deep motives which supported it.

Similarly, blood vengeance once existed almost the world over. The death of a member of one's own family must be avenged, it was felt, by taking a life from the family that caused the death. Even so mild a statesman as Confucius believed that a lesser official could not live in the same country with one who had killed a high officer of state: that a subordinate must personally see that the death of his superior was avenged.

Yet the institution of private blood-vengeance has been done away with, and without requiring human nature to change by so much as a hair's breadth. We simply have instituted better methods of satisfying the ancient human impulses, while leaving the impulses

themselves strong and untouched. In the same way one might speak of piracy and of duelling, which also have been virtually abolished while human nature remains unchanged.

But I hasten on to slavery, which comes closer to us, and whose abolition is within the memory of men who still live. Slavery's hold is from earliest times. The enslavement of others has marked the leading peoples of the world. Civilization itself has seemed impossible without it. Only yesterday the living bodies of men and women were bought and sold even in our own land.

But when the time came for Lincoln to sign the great Proclamation, did he by one jot or tittle have to annul the laws of human nature itself? No. He left men, as before, to be avaricious still. They still are ready to use other men for their own interests. But men have been prohibited from buying and selling men as one buys cattle.

Now is war, in its relation to human nature, essentially different from these other forms of social behavior which have disappeared? War unquestionably is one of the modes in which our nature finds expression. So deep are war's foundation, so firm its iron hold, that all thoughtful men will have at times almost some touch of despair that there can be success against it.

And yet despair is not scientifically justified. Confidence of success here can be had without forgetting or distorting human nature. Hope can be held without shutting one's eyes to the plain facts of psychology. It may well be true that in all its large outline human nature does not change. And yet our experience shows that our unchanging nature permits important changes in human conduct. Indeed, under the stimulation of social enterprise, human nature not only permits but demands profound changes.

We cannot doubt that humanity will keep the great impulses which still lead to war,—among which is the love of wealth, the love of adventure, the love of honor, the love of Mother Country. Yet there can be a growing impatience, a growing abhorrence of satisfying these great impulses by the old bloody methods. Nor is there in the science of psychology anything to assure us that in this one region no further advance is possible; to assure us that here men have reached the last limit of their inventiveness; that they can institute no shrewder, no more satisfying devices to express their devotion to their own nation's life and to the life of the world.

Within wide limits human nature does not change. Yet we are wholly wrong if we suppose that, for the end we here have in mind,

it needs to change. Great things have been done for humanity while human nature has remained the same. Our civilization has been rid of human sacrifice in religion, of private blood-vengeance in our civil life, of piracy upon the high seas, of slavery in all our leading communities. Every one of these social institutions has had the support of men's permanent passions, of men's deep impulses. To rid the world of these ancient instruments it has not been necessary to rid the world of men. Nor have we needed to wait until all sinners have been changed to saints. It has been necessary merely that men should be socially progressive, inventive, adventurous. Men have had to coöperate with one another untiringly to change the old habits of their life. New ways of justice and law and order have had to be viewed with hospitality, without a too tenacious clinging to the cruder and less effective ways.

Human nature plays a double rôle. It runs with the hare and hunts with the hound. It expresses itself by remaining in the old, by reverting to the old. But it expresses itself no less by leaving the old, by moving to the new. It has not stood as a wall against progress. The advance, the untiring search for more effective institutions of justice, for more effective ways of meeting the rival claims of large groups of men,—these changes also are an utterance of our nature. The deepest forces behind human conduct do not merely oppose civilization; they press us to be more and more civilized. Human nature resists progress; but in all leading lands it also overcomes its own resistance, its inertia and habits, its own conservatism. Out of our human nature have come the motives, the human instruments and leaders, the intelligence, the insistent urging, which have enriched and strengthened our civil life. And these same great forces, psychology in no wise forbids us to expect, will bring the more favored nations to coöperate in establishing a better institution than war to do the work of war. Three of the Four Horsemen and not two only, we may hope will cease to scourge the world.

G. M. Stratton in *Daily Science News Bulletin*, No. 262F.

Special Question

Note that this is an example of multiple analogy. What are the points of similarity between war and each of the three institutions which have been abolished? How are the differences disposed of by Professor Stratton? Can you find any defect in his argument? Do you think that he proves conclusively by this multiple analogy that war can be abolished? Give reason for your answer.

13. Insect Psychology

Scientists are giving us grounds, very practical grounds, on which we may talk of insect psychology, and when we study their works we cannot help noticing the remarkably close similarity between this psychology and our own. Thus Melissa (the name of an individual honey-bee) flies! I will venture beyond the strict accuracy of ascertainable fact and dare the surmise that she is happy, and that only in recent times (since the discovery of the airplane) has it been made possible for human beings to know just how happy she may be. We, too, spend most of our time in youth in dark, warm places; we, too, may one day rush to a jumping-off place; and we, too, can wing our way into the air, into the blue sky and the golden sunshine. Throwing all caution to the winds, I suggest it must be even more wonderful for Melissa than for us. And those who are so fond of asserting the superiority of the human over the insect race need not retort with reminders about honey-gathering and duty. Nothing of the kind. Melissa is flying for fun and for fun only.

Adapted from *Discovery,* Vol. VII, pp. 179, 181.

14. An Example of False Analogy

We know it to be true of every organism that the rhythm, form and duration of its life, and all the expression-details of that life as well, are determined by the *properties of its species.* No one, looking at the oak, with its millennial life, dare say that it is at this moment, now, about to start on its true and proper course. No one as he sees a caterpillar grow day by day expects that it will go on doing so for two or three years. In these cases we feel, with an unqualified certainty, a limit, and this sense of the limit is identical with our sense of the inward form. In the case of higher human history, on the contrary, we take our ideas as to the course of the future from an unbridled optimism that sets at naught all historical, i.e., *organic,* experience, and everyone therefore sets himself to discover in the accidental present terms that he can expand into some striking progression-series, the existence of which rests not on scientific proof but on predilection. He works upon unlimited possibilities—never a natural end—and from the momentary top-course of his bricks plans artlessly the continuation of his structure.

"Mankind," however, has no aim, no idea, no plan, any more than the family of butterflies or orchids. "Mankind" is a zoölogical expression, or an empty word. But conjure away the phantom,

break the magic circle, and at once there emerges an astonishing wealth of actual forms—the Living with all its immense fullness, depth and movement—hitherto veiled by a catchword, a dry-asdust scheme, and a set of personal "ideals." I see, in place of that empty figment of one linear history which can only be kept up by shutting one's eyes to the overwhelming multitude of the facts, the drama of a number of mighty Cultures, each springing with primitive strength from the soil of a mother region to which it remains firmly bound throughout its whole life-cycle! each stamping its material, its mankind, in its own image; each having its own idea, its own passions, its own life, will and feeling, its own death. Here indeed are colours, lights, movements, that no intellectual eye has yet discovered. Here the Cultures, peoples, languages, truths, gods, landscapes bloom and age as the oaks and the stone-pines, the blossoms, twigs and leaves—but there is no ageing "Mankind." Each Culture has its own new possibilities of self-expression which arise, ripen, decay, and never return. There is not one sculpture, one painting, one mathematics, one physics, but many, each in its deepest essence different from the others, each limited in duration and self-contained, just as each species of plant has its peculiar blossom or fruit, its special type of growth and decline. These cultures, sublimated life-essences, grow with the same superb aimlessness as the flowers of the field. They belong, like the plants and the animals, to the living Nature of Goethe, and not to the dead Nature of Newton. I see world-history as a picture of endless formations and transformations, of the marvellous waxing and waning of organic forms. The professional historian, on the contrary, sees it as a sort of tapeworm industriously adding on to itself one epoch after another.

OSWALD SPENGLER, *The Decline of the West,* translation by C. F. Atkinson (copyright, 1926, by Alfred A. Knopf, Inc.), pp. 21*f*.

Special Questions

1. What conclusion is drawn from the analogy by professional historians?
2. What conclusion is drawn by Spengler?
3. Which do you think commits the fallacy of false analogy? Give reason for your answer.

15. The Obstinate Juryman's Case

Two men were seen fighting together in a field. One of them was found, soon after, lying dead in that field. Near him lay a pitch-

fork which had apparently been the instrument of his death. This pitchfork was known to have belonged to the person who had been seen fighting with the deceased; and he was known to have taken it out with him that morning. Being apprehended and brought to trial and these circumstances appearing in evidence, and also that there had been, for some time, an enmity between the parties, there was little doubt of the prisoner's being convicted, although he strongly persisted in his innocence. But, to the great surprise of the court, the jury, instead of bringing in an immediate verdict of guilty, withdrew and, after staying out a considerable time, returned and informed the court, that eleven, out of the twelve, had been, from the first, for finding the prisoner guilty; but that one man would not concur in the verdict. Upon this, the judge observed to the dissentient person, the great strength of the circumstances, and asked him how it was possible, all circumstances considered, for him to have any doubts of the guilt of the accused? But no arguments that could be urged, either by the court or the rest of the jury, could persuade him to find the prisoner guilty; so that the rest of the jury were at last obliged to agree to the verdict of acquittal.

This affair remained, for some time, mysterious; but it at length came out, either by the private acknowledgement of the obstinate juryman to the judge who tried the case (who is said to have had the curiosity to inquire into the motives of his extraordinary pertinacity), or by his confession at the point of death (for the case is related both ways), that he himself had been the murderer! The accused had, indeed, had a scuffle with the deceased, as sworn on the trial, in which he had dropped his pitchfork, which had been, soon after, found by the juryman, between whom and the deceased an accidental quarrel had arisen in the field; the deceased having continued there at work after the departure of the person with whom he had been seen to have the affray; in the heat of which quarrel, the juryman had unfortunately stabbed him with that very pitchfork, and had then got away totally unsuspected; but finding, soon after, that the other person had been apprehended, he had contrived to get upon the jury, as the only way of saving the innocent without endangering himself.

S. M. Phillips, *Famous Cases of Circumstantial Evidence*, No. XXI, quoted by J. H. Wigmore in *The Principles of Judicial Proof*[2] (Little Brown and Co.), pp. 166*f*.

[2] Professor Wigmore's book contains many other examples of circum-

16. The Tucker Case

On the last day of March, 1904, there lived on South Avenue, Weston (Mass.), a family named Page. The house had been their summer home for over twenty years; they dwelt in Boston during the cold weather. For the past five or six years, however, they had lived in Weston all the year, only one member of the family going daily into the city. Mr. Edward Page had retired from business; he was about seventy-eight years old. His wife had died nearly two years earlier. His son Harold, a clerk in the freight office of the Boston and Albany Railroad, in the South Station, took a train for Boston about eight every morning. He was fond of shooting and fishing; he bred and kept a few dogs, and sometimes sold one of them. His sister, Miss Mabel Page, a woman about forty-one years old, and the housekeeper, Amy Roberts, made up the rest of the family.

March 31st was one of the deceptive days of early spring, beginning with such promise as to lure walkers into the country roads; growing colder and more threatening as the afternoon came on; and finally ending in a return to winter. Mr. Harold Page departed for the city at the usual time. His father set out on a ramble at about half-past nine. The housekeeper, an hour later, went away for the day. Miss Page gave her money for her expenses and for some shopping. Miss Roberts observed that she returned a ten dollar bill, and one or two others, to a purse, which she replaced in the drawer of a table. Then the housekeeper went on her way by the street-car to Watertown; to Cambridge, where she consulted her physician; and finally into Boston for her shopping. Before eleven o'clock Miss Page was left alone in the house; this, perhaps, was not a frequent occurrence, but it would have caused her no uneasiness. The house was in sight of others; the neighborhood was quiet and peaceful.

The elder Mr. Page went to the post-office at Auburndale; there is little or no division between the towns and villages in this region. A neighbor's coachman had been sent to drive him over to Auburndale, and after his arrival there he waited a few minutes for the opening of the public library, at ten o'clock. He had intended to go in town, but abandoned the idea on reading in the morning paper that a storm was predicted. He read until noon, when the library

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stantial evidence. Teachers and students of logic will find it an exceptionally valuable source book for illustrations of reasoning in law.

closed for two or three hours. He walked toward Waltham, called at a friend's house and then made his way back to Auburndale, where he inspected a stable recently built by another of his friends. The coachman's wife opened the stable and showed him about in it. Then he returned, walking slowly, and resting from time to time, to his own home in Weston. He arrived there at about two o'clock.

The pleasant spring morning had attracted more than one other rambler into those roads and lanes. One of them was a resident of Auburndale, a young man named Charles Louis Tucker. He was a widower of twenty-four; his wife had died a little less than a year earlier. He had been in various occupations,—working for one of the men who let boats at Riverside, where everybody goes for boating or canoeing on the Charles; in the South Station, as baggage clerk and elevator boy; and recently at Thorp and Martin's, the Boston stationers. He had seen and known Mr. Harold Page for six years, but the acquaintance was slight; Mr. Page knew only his last name. On two occasions he had been at the Page house for a few moments. In 1902, he called one Sunday, talked with Mr. Page and his sister, entered the house for a while, visited the barn and bought a dog. On this day in March, 1904, however, Mr. Tucker was not in employment; his were idle hands.

He was regarded by some of his acquaintances as a harmless young man, and it was in token of this, perhaps, that they called him "Tommy Tucker." While the elder Mr. Page was wandering about Auburndale and Weston, Mr. Tucker also went for a stroll. According to a description of it which he gave later, it was an excursion both idyllic and innocent; by another version, which he found it wise to impart to a selected few, it was still idyllic, but not precisely innocent; a third and harsher description of his perambulations, never assented to by Mr. Tucker, denied it either of these qualities. At any rate, he said that he spent the morning dutifully working on the lawn of his parents' house. At noon, he changed his clothes and ate his mid-day meal. Then he walked down to the bridge at Weston; he named some persons who saw him. He walked up to South Avenue; at one place he saw a man digging in a trench. Everybody—Amy Roberts, Mr. Tucker, and everyone else—saw this man in the trench and remembered him, and it is not to be wondered at, for he bore an illustrious name: Mr. Dooley. Tucker loitered at one place to watch a squirrel—a winsome incident—and returned to his home about one o'clock.

He did not go in, as he met a friend, one Bourne. Together they walked down to Weston bridge again. Here they met a youth named Arthur Woodward driving a fish-wagon. Woodward may not have interested them especially, nor his fish, but his companion did. She was named, so it appeared, Mabel Walker, and her home was in Damariscotta, Maine. She waved her handkerchief and, like Woodward, seemed disposed to sociability. The two young men accepted an invitation to drive for a while on the fish-wagon. Mr. Tucker sat on a seat, between Woodward and the young lady from Maine. Mr. Bourne clambered into the rear of the wagon,—amongst the fish. After a while the company of the driver, of Bourne, or the fish, began to pall upon the other two, and they dismounted, and went for a walk together. They went over to the athletic grounds to watch the trap-shooting.

Finally Tucker bade Miss Walker good-bye, and returned to his home. There was at least one incident in connection with this day which he did not mention. He had carried with him—rather unnecessarily, for a morning's walk in the vicinity—a hunting knife in a sheath,—a knife with a blade about five inches long.

A little after eleven a man named Maynard came to the Page house delivering laundry. He rang at the front door and left a package with Miss Page. No other person was seen to come. At about ten minutes after two, Mr. Edward Page returned. He went to the rear door and found it fastened; he went to the front, and that door, contrary to custom, was unlocked. He opened it and went in. . . . Mr. Page went to the pantry and had something to eat: a slice of bread and a glass of cider. He sat down and ate at leisure, for perhaps ten or fifteen minutes. Then he returned to the front room, where he observed his daughter's work as she had left it: a dress, her sewing basket and thimble. The house was very quiet, and it struck the old man as unusual that he did not hear his daughter anywhere. He decided to go upstairs to look for her. At the head of the stairs he was surprised to find the two doors of Miss Page's room closed; ordinarily they were open in the day to light the staircase. He opened one of the doors and looked in. His daughter was lying on her back on the floor; the eyes were open and seemed to look at him. She was fully clothed except that she wore an underskirt, but no overskirt. She wore a hat and walking boots as if she had been about to go out.

Mr. Page felt his daughter's hand and found it cold. He tried to listen to her heart-beat; he spoke to her, but she was dead. He

saw blood on the floor, and looking at her throat saw a jagged wound in the neck. After a short time, he went down-stairs and looked about in the main living-room. He noticed that the fire in the open fire-place had gone out; had been put out, apparently, by the removal of the two logs so that they lay beside the andirons. On a table he found a small slip of paper, bearing a message in Miss Page's handwriting. This note is an odd and almost inexplicable feature; I do not recall a parallel instance in any other case of which I have read. It was as follows:

> Have just heard that Harold is hurt and at the Massachusetts Hospital. Have gone in 12 o'clock. Will leave key in front side door with barn key. Will telephone Mrs. Bennett.

Mr. Page went out to summon help, to ask the neighbors for assistance, to send for a doctor, and to learn what had happened to his son. By means of the nearest telephone, in Mrs. Bennett's home, he got into communication with the South Station in Boston, and asked about Harold Page. The answer was that the young man was there and would speak for himself. Nothing had happened to him; he had not been hurt. He was told by his father, of his sister's death, and started for home. He went first to the home of a married sister who lived in town, and left word of the death with her.

A doctor came during the afternoon, and another, the Medical Examiner, at about six o'clock. By that time it was not only dark but stormy, a snow-storm. The doctors viewed the body by the uncertain light of hand-lamps, and to them the wound in the throat seemed to resemble the awkward gash often made by suicides. They talked with the family, but were unable to come to any decision. The Medical Examiner left a note for the undertaker, telling him not to embalm the body until a further examination had been held. When the undertaker came, at midnight, he found two other wounds: one in the chest and one in the back. The latter wound, together with the absence of a weapon, disposed of any theory of suicide. The Medical Examiner was sent for again, and the police were notified that this was a murder. Death had been caused by the wound in the chest which had penetrated the heart. This, and the wound in the throat, were each of a depth of five inches. The overskirt of the dead woman was found on the floor near the body. The hooks which held the waist had been pulled out, and red fibers of a straw carpet were found embedded in the skirt. As there

were no red fibers in the carpet in the bed-room, where her body was found, and as there were in the carpet in the hall outside, and in the room downstairs, it was apparent that the murder had occurred elsewhere, and that the body had been dragged into the bedroom. Another curious bit of writing was found in the house; in the room with the body. It was placed on the floor, and seemed to have been deliberately placed to attract attention. It bore, in pencil, the words: "J. L. Morton, Charlestown, Mass." It was written in a back hand, some of the letters started one way, and then started again, and written over. The handwriting was not that of anybody in the family. From the purse in the room downstairs, the purse in which the housekeeper had seen twelve or more dollars in bills that morning, all the money, except for some change, was missing.

The newspapers were rather impatient with the police for not making an immediate arrest. The murder was so brutal, so unexplainable and unusual, that it caused a great sensation. All who had been in the neighborhood were questioned, and the accuracy of their statements investigated. Four days after the murder, Tucker, merely as a person known to have been nearby, was asked for an interview by the police. He told them the story of his walk, of his work and his amusements on that day, practically as it has been related here. He was not put under arrest; there was no direct cause for suspicion against him. At the end of the interview, he was permitted to go home. But the papers printed the fact that he had been at the police-station, and published his picture. This, in *The Boston Post*, fell into the hands of young Woodward, the driver of the fish-wagon, and thereby served the cause of justice. Woodward disclosed to his father a certain fact, and showed him an interesting object. It was the leather sheath for a knife. He had found it on the seat of the wagon, a few moments after Tucker had left him on March 31. On finding it, Woodward put it into his pocket and took it home; it carried no suggestion for him until, five days later, he read of Tucker's association with the crime. The sheath was for a knife about five inches in length; there were the marks of teeth in one corner of it. The elder Woodward notified the police of Weston, and handed over the sheath to them. . . .

Tucker was taken again to a police-station and given the usual warning of his right to answer questions or not as he chose, and of his risk, if he spoke, of having his words used against him. He was asked if he owned the sheath of a knife, and he denied that he

did. An officer who was examining one of his overcoats, then held up this sheath, and asked if it were his. He then admitted it, and said that on the third day after the murder, fearing that he was suspected, he had taken the sheath from a drawer in his room, and put it into the overcoat pocket to conceal it from the police. (This was the sheath, which, all the time since the day of the murder, had been in Woodward's possession). He denied that he had ever owned a hunting knife, except one which he had sold a year before, and one which he had lost in the river two years earlier. He permitted a dentist to take a cast of his teeth, and it was found to correspond with the marks of teeth on the sheath. During this examination his house was searched. In the pocket of a coat in his room, were found three fragments of a knife blade; the handle was missing. The blade had been broken, twisted, and filed. But it was found to be a blade originally about five inches in length; it bore blood-stains. In the pocket with it was a pin with a Canadian emblem, afterwards declared by Amy Roberts to be Miss Page's property. Tucker was shown the broken knife-blade, and he now admitted that it belonged to him, and said that he tried to destroy it when he became aware that he was suspected by the police. At the end of the questions he was placed under arrest....

More than nine months after the murder, on January 2, 1905, Tucker was put on trial. . . . The case depended entirely upon circumstantial evidence. Nobody had seen Tucker enter or leave the Page house. The Government sought to prove that he had the opportunity to commit the murder; that he was in the vicinity. That he had the motive of theft, and that this was proved by his possession not only of the "Canadian emblem," but of a ten dollar bill and other money which he had shortly after the crime, although he was known to be without money before the crime. . . . That his knife fitted the wounds and the tears in the clothing of the dead woman, and that he had attempted to destroy evidence by the breaking of this knife. That he had told lies about his whereabouts at the time of the murder, and about his possession of the knife, sheath, and pin. And that the "J. L. Morton" note was in his handwriting, and had been left in the house to divert suspicion. They produced a witness named J. D. Morton, who worked, as Tucker had formerly done, in the South Station. The inference was that the similar name was one which might have occurred to him, or possibly he might have presented himself at the house under that name. . .

The defense contested all these assertions of the Government. They produced witnesses to try to corroborate the prisoner's statements about his walk on March 31; to prove that the pin was his own, that they had seen him wearing it in his cap before the murder; and to break down other points made by the prosecution. Some of these witnesses were evidently partisan, some appeared to be perjured, and their general effect was not advantageous to the prisoner. . .

The prisoner did not testify in his own behalf. . . Before the charge was given to the jury, he was permitted to address them. He did not have the good judgment to confine his remarks to thirteen words but made a speech of two or three minutes' length. In it he said little of importance, except to deny his connection with the murder, to give a much expurgated account of his doings on March 31, to deny that he wrote the Morton note, to say that he broke up the knife because he was frightened when the police began coming to his house, and to describe himself on the day of the murder as "happy as any boy could be."

On the twentieth day of the trial, January 24, the jury went out at about 2 P.M. . . . Shortly after ten o'clock they gave in their verdict: "Guilty of murder in the first degree."

From E. L. PEARSON, *Studies in Murder*[3] (copyright, 1925, by the Macmillan Co.; reprinted by permission), pp. 232-248.

Special Questions

1. Do you think that Tucker was guilty?
2. Do you think the Government proved him to be guilty?
3. List the chief similarities between Tucker and the murderer.

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[3] This volume contains other highly interesting illustrations of circumstantial evidence. See also his *Murders at Smutty Nose and Other Murders*. Tucker was sentenced to die by electrocution and the sentence was ultimately carried out.

In *The Case of Sacco and Vanzetti* Professor Felix Frankfurter gives an excellent detailed analysis of the circumstantial evidence offered in one of the most celebrated cases in the history of American criminal law. Originally published in the March, 1927, number of the *Atlantic Monthly*, it is now obtainable in separate form from the Atlantic Monthly Bookshop. It is recommended that students be asked to make a written analysis of Professor Frankfurter's reasoning.

CHAPTER VII

ASSUMPTION AND HYPOTHESIS

The ultimate aim of the scientist is to find a principle which will be a complete explanation of the problem with which he happens to be concerned. If he is a true scientist he will never give up the study of his data until he has attained this unifying principle. Now there are various names which have been given to such an explanatory principle and which are, therefore, frequently regarded as synonymous. Such names are *axiom, postulate, assumption, hypothesis, theory* and *law.* It is a mistake to treat all of these words as synonyms, but it is correct to regard them as various expressions of the three chief stages in the working out of an explanatory principle.

The first stage is the recognition that the known laws of nature or some other general principles must be used as a basis for any new investigation. The scientist has to take some principle or principles as the starting point. When he begins a piece of research his mind is never, as it were, in a vacuum. Now any principle or set of principles used as the basis for a further investigation may be regarded as an assumption or set of assumptions, so far as that particular piece of research is concerned. It is not necessary here to make a distinction between an axiom or postulate and an assumption. Let us regard these three words as synonyms standing for the general principle or set of principles which are taken for granted in an investigation and which are used by the research worker in reaching a fuller understanding of his problem. Assumptions, then, constitute the first stage in explanation.

Working hypotheses constitute the second stage. Any conception used to establish a connection between the various data of an investigation, so long as it is regarded as being only one among a number of alternative conceptions and is not

yet treated as a law inherent in the data, is called a working hypothesis. Most scientists recognize that there is a decided advantage in formulating multiple working hypotheses. Hence, given his assumptions and his data, the scientist usually tries to suggest as many explanations as he can possibly conceive. These are then compared and fused into a few definite conjectures. Such conjectures, products of the imagination and intelligence of the scientist, are working hypotheses, and formulating them constitutes the second stage in explanation.

Then follows the final stage. By a process of testing and molding there will emerge from these multiple working hypotheses one that will stand all tests better than any other. It may be one of the original tentative conjectures or it may be a new principle made by fusing or synthesizing these. This process of reducing the hypotheses to one, of fitting the various tentative suggestions to the data, is known as verification. The verified hypothesis is a theory, but it may also be called a law. Thus we call the Newtonian explanatory principles laws of motion, but we call the Einstein principle the theory of relativity. Most people, however, and even many scientists use the words law, theory, hypothesis, assumption and postulate more or less interchangeably. This is justifiable in the sense that a law or theory, once established, becomes an assumption to the next investigator in that field in as much as he has to take it for granted and base his conclusions upon it.

In this chapter we are concerned with assumption and hypothesis. In the next we will consider the various ways in which hypotheses are verified and molded into a single explanatory principle or theory.

WHAT TO READ

Read Appendix II and one or two of the following:

Columbia Associates, *Introduction to Reflective Thinking,* pp. 35-61.
Creighton, J. E., *An Introductory Logic,* Chap. XIX.
Cunningham, H. E., *Textbook of Logic,* Chap. XIX.
Jones, A. L., *Logic, Inductive and Deductive,* Part III, Chap. II.
Joseph, H. W. B., *An Introduction to Logic,* pp. 464-475.
McClure, M. T., *An Introduction to the Logic of Reflection,* Chap. IX.
Mellone, S. K., *An Introductory Textbook in Logic,* pp. 320-332.

ROBINSON, D. S., *The Principles of Reasoning,* Chap. XXIV. See also Chap. XXII.
SELLARS, R. W., *Essentials of Logic,* Chap. XVIII.
WELTON, J., *Manual of Logic,* Vol. II, Chap. IV.
WELTON and MONAHAN, *An Intermediate Logic,* Chap. XXVIII.
WESTAWAY, F. W., *Scientific Method,* Chap. XXI.
WOLF, A., *Essentials of Scientific Method,* Chap. VII.

The best brief discussion of assumption is Josiah Royce's article entitled *Axioms,* in Hastings' *Encyclopedia of Religion and Ethics.* He distinguishes five different meanings of the word axiom, of which the third or logical meaning is the same as that given above.

WHAT TO DO WITH THE EXAMPLES

1. State briefly and clearly each assumption you find in any of the examples. If none are stated in the example, state those you think are implied.
2. Draw up a list of the hypotheses mentioned in each example.
3. Tell which hypothesis in the list you think is most likely to be the true explanation and tell why you think so.
4. From what science is each example drawn?

1. The Nature of Atoms

Atoms are composed of two kinds of electric particles, the protons and the electrons. The electrons are electrified negatively; the protons are positive. It is commonly assumed that one proton is the exact equivalent, although the opposite, of one electron.

But, says Professor Swarm, of Yale, is this necessarily and exactly true? It is admitted that the proton and the electron *almost* balance each other. Many facts prove this. But possibly the balance is not quite exact. . . This would provide a tiny residual electrification. It might easily explain the mysteries both of earth electricity and of earth magnetism. More still, it might give us a clue to the nature of that greatest and most universal of mysteries, the utterly unexplained marvel of gravitation.

Forum, Vol. LXXV, illustrated section, p. xlvi.

Special Questions

1. Would it be justifiable to treat this as an example of Mill's method of residues rather than as an example of assumption? Give reason for your answer.
2. How does Professor Swarm's assumption differ from the common assumption? Which seems to you to be most plausible and why?

2. Stellar Evolution

During the past fifteen years the astronomers have been formulating an idea of stellar evolution, according to which a star is supposed to pass through a more or less uniform series of developmental stages. First it is a great body of shining gas, very thin and not especially hot. Gradually it grows smaller, denser, and hotter. It becomes a white star. Then it slowly cools, growing denser and yellower as it does so. The final stage, before all luminosity is lost, is one of small size, considerable density and reddish color.

In working out the details of this hypothesis Eddington has been compelled to assume that the course of evolution of a star is accompanied by a change in the source of supply of its energy. It is this change, in fact, which determines the evolution. In the beginning, Eddington imagines, the vast globe of the star contains a comparatively large proportion of some kind of matter which is rather easily disintegrated, with the evolution of energy. This matter may be thought of as composed of atoms still more radio-active than radium. The disintegration of these atoms produces the energy of the star.

As the star grows older these easily disintegrated atoms are gradually used up. The energy output of the star must come from more and more difficultly decomposable kinds of matter. Finally, nearly all of the decomposable matter is gone. The remaining kinds of atoms do not disintegrate. Then the star cools off and dies and becomes like our earth.

Idem, p. xl.

Special Question

How are the details of Eddington's hypothesis related to his assumption as stated at the beginning of the second paragraph?

3. The Destiny of Starlight

One of the most puzzling and interesting questions in the whole field of physical science is "What becomes of all the energy which is being sent off into space by the radiation of the stars?"

One suggestion is that it goes off into the dark depths of space to be lost forever, but since experimental evidence proves that light is not weakened by mere passage through space, this idea does not seem to hold.

Three other ideas have been suggested. One is that the universe is strictly limited, being only a little local cloud of nebulæ,

stars and other objects lost in a vast void. A second is that space contains clouds of dark matter which hides the more distant stars from our view. The third idea is that of the followers of Einstein that space is "warped" and the rays of light are bent into a circle in traveling through space. All of these ideas are beset with serious difficulties.

There has been urged, however, another idea which is extremely interesting. This is the idea of Sir Oliver Lodge that the lost starlight is converted, somehow and somewhere, into matter. If this change takes place in one direction in the stars, matter being there converted into energy, it ought to be possible for it to take place in the reverse direction in empty space, energy being there reformed into matter. But this is admittedly no more than a guess.

Idem, p. xlii.

Special Question

What is the relation of this to the preceding example? Is Sir Oliver Lodge's hypothesis based on the Eddington hypothesis as an assumption?

4. The Destiny of the Planets

The solar system needs a cosmic trust-buster, if the smaller planets are to remain in business. According to the astronomical calculations of Professor W. D. MacMillan of the University of Chicago, all the planets are very slowly gaining in size by sweeping up stardust as they travel through space, and in time they will reach a size that will cause them to attract each other more strongly than at present. When this stage is reached, monopoly will begin its deadly work; the larger planets will gobble up the smaller, and in the end Jupiter, the largest of the lot, will absorb all the rest, even Uranus and Neptune, the giant worlds in the suburbs of the solar system. After that the system will be a double star, consisting of the sun and the monopolist Jupiter. . .

When the solar system reaches the double-star stage, it will not be all alone by any means, for many of the visible stars are binaries or doubles. Some of the double stars consist of one large, bright body and one smaller, dimmer one; or the smaller star of a pair may even be entirely dark, betraying its presence only by eclipsing its companion at regular intervals.

It may be the fate of the planets to become such a dark star when they combine, for at present they give forth no light of their own. Or the energy of their collisions may warm them up so that

they will shine with a dim light, like the small faint companion of Sirius, the dog-star.

Daily Science News Bulletin, No. 242D.

Special Questions

1. Upon what assumption does the main hypothesis in this example seem to you to rest? Do you think that it is justifiable?
2. What two subsidiary hypotheses are implied in the last paragraph?

5. Some New Hypotheses in Geology

Professor W. M. Davis of Harvard assures us not only of the value of hypotheses, but of the value of outrageous ones. Speaking as a geologist, he assures his fellow scientists that since the great advances of geology in the past have been made by outraging in one way or another a body of geological opinion, we may be pretty sure that the advances yet to be made in geology will at first be regarded as outrages upon the accumulated convictions of today, which, as the modern substitute for Genesis itself, we are too prone to regard as geologically sacred.

The very foundation of geology, he says, is only an inference, for the whole of it rests on the improbable assumption that all through the lapse of time which the inferred performance of inferred geological processes involves, these processes have been going on in a manner consistent with the laws of nature as we know them now. If we cease to accept these assumptions, the idea that the earth is shrinking and cooling may have to be abandoned. What if it is still heating itself up by the slow compression of an originally uncompacted interior under the weight of a heavy exterior? What if it possesses an expanding interior which, like the caged starling, "wants to get out?" Then the Wegener outrage of "wandering continents," the Joly outrage of "periodical sub-crustal breaking out" become serious possibilities. Our notion of the origin of mountains would then once more be in the melting pot, for the influence of horizontal thrusts and erosions would no longer be as stated in the textbooks.

Professor Davis does not believe in the idea of an expanding earth himself, but he sets it forth as an outrage; and it may serve as a symbol of our expanding horizons in general, of a greater tolerance due to a wider understanding both of the workings of the universe and of the workings of our own minds.

Forum, Vol. LXXVI, illustrated section, p. xxv.

Special Questions

1. Upon what assumption is traditional geology based and why does Professor Davis call it improbable?
2. What hypothesis about the earth rests upon this assumption and on traditional geology?
3. Are the new ideas about the earth in paragraph two assumptions or hypotheses? If hypotheses, upon what assumption are they based?

6. The Origin of Oxygen

A new idea of the origin of free oxygen in the atmosphere has recently been proposed by Professor G. Tammann of Göttingen. He suggests that it was probably formed during the cooling of the earth in the period between the beginning and the end of the solidification of the uppermost layer of the crust. He calls attention to the fact that investigations of the gases contained in eruptive rocks have shown that these never comprise free oxygen, but always consist exclusively of carbon dioxide, hydrogen and nitrogen. This implies that when the silicate-containing rocks were first solidified, there was still no oxygen in the atmosphere, which probably consisted of large quantities of water-vapor mingled with nitrogen, hydrogen, carbon dioxide and carbon monoxide. He says: "The solidification must have begun at the temperature at which water vapor is decomposed—at least a small part of it—into hydrogen and oxygen. It has been shown by careful calculation that at this temperature hydrogen is able to overcome the attraction of gravity and escape into space, the oxygen remaining behind."

Literary Digest, Feb. 27, 1926, p. 24.

Special Question

What effect would the change in assumptions about the earth suggested by Professor Davis in the preceding example have upon the hypothesis suggested by Professor Tammann?

7. The Nature of the Earth

Water imprisoned inside the earth blew off as steam, condensed and formed the seas, in the opinion of Dr. W. J. Humphreys of the Weather Bureau. Other scientists are discarding the hypothesis that the center of the earth is a molten mass, and believe that the core may be a solid ball of iron or iron-nickel alloy nearly four thousand miles thick. The surface crust, one authority estimates, is not over thirty-six miles thick. It is lighter than the interior and

may be separated from the core by a fluid or semi-fluid layer. One scientist holds that the earth was probably once a part of the sun's atmosphere. A passing star, attracting the sun, caused some of its atmosphere to break loose, and on cooling, it formed this planet.

Popular Mechanics, Vol. XLVI, p. 258.

Special Questions

1. How many different hypotheses as to the nature of the inside of the earth does this example contain?
2. If any of them is true, what effect would it have on the hypothesis stated in the preceding example? Why would it have this effect?

8. Wegener's Theory of Continental Drift

Wegener is well known for his startling theory, launched a few years ago, concerning the movement of the continents over the surface of the earth. . .

The theory is based upon a great number of lines of evidence, in each of which the experts must have their say before we can feel sure of our ground; and, as regards the idea of continental movement, the experts are still in total disagreement among themselves. Probably the final incorporation of the theory into the body of scientific principle, or its final rejection, will be delayed until time enough has elapsed for a perfectly definite answer to be given, by means of accurate determinations of longitude, to the question whether or not the continents are actually shifting position relative to each other; and that will not be for some decades. . .

Wegener's original thesis, in briefest space, was this—that the continents, though essentially permanent as continental masses, as blocks of land most of whose surface projected above sea-level, are not fixed in position, but are slowly though continuously drifting from place to place under tidal influences. Some masses are more firmly anchored than others, so that there may be relative motion between different continents. Wegener maintains that the American continent is now drifting westward, relative to the great land mass of Europe, Asia, and Africa, at the rate of a yard or so a year; that it was once, in times not so geologically remote, continuous with that land-mass; and that it split off along a crack now represented by the margins of the continental shelf on either side of the Atlantic—in witness of which he points out that a great part of these two margins will even to-day, in spite of all the deformation which they have presumably undergone, fit into each other,

as you may see by a look in the atlas at the west coast of South America and the east coast of Africa.

He supposes further that the continents are composed of materials essentially different from the deeper mass of magma below; they are the crust of surface slag into which, during the long processes of earth cooling, certain types of elements have become segregated according to natural laws. Over the deep oceans there is now no crust, the naked magma here coming to the surface; and the blocks of crust float in the magma like icebergs in the sea or, to use a simile which takes a little more account of the viscidity of the magma, like pieces of toast in a lake of treacle.

Tidal friction is always tending to move the crustal masses westward; hence the fact that great mountain ranges are usually found upon the western sides of continents, near the sea—the crumplings of the crust as it ploughs its westward way. Further, when lines of weakness develop in a big piece of crust, then if the eastern side is better anchored, the western part will tend to split off and start life as an independent continent. Wegener believes that the Red Sea and the Great Rift Valley of Africa are such incipient splits.

Many important consequences would flow from the acceptance of such a theory. In the first place, the zoölogist would be relieved of much embarrassment in accounting for various facts of geographical distribution. For instance, there can be very little doubt that Australia was at one time able to interchange land animals with South America via the Antarctic continent. But to have done this, land bridges would be necessary, and the one from Australia to Antarctica would, on the present distribution of land and sea, have to have existed across a deep ocean—a hypothetical construction which almost all geologists refuse to allow us. If, however, Wegener is correct, then Australia was in the past actually connected with Antarctica, and has since drifted away (incidentally, according to our author, shoving its nose into various chains of islands and deforming them with the momentum of its progress), carrying into isolation its menagerie of primitive animals free to develop without competition from later products of evolution. Then, again, it would at least help us to understand that most puzzling fact of the apparent changes of climate which have overtaken various parts of the world's land-surface. The most familiar example is the existence, in lands at present Arctic, with no vegetation above a few inches in height, of coal beds testifying through their contained fossils to the past existence of tropical or semi-tropical warmth and

abundant forest trees. The Spitzbergen region, to take but one instance, has experienced no fewer than four separate coal-forming periods. Wegener supposes that the position of the continents relative to the poles has changed, partly through their own wanderings, partly through an alteration of the polar axis itself, which would be consequent upon the upset of the earth's equilibrium caused by the continents' wanderings. This would make it possible for one and the same country to have passed through all the extremes of climate during its long history.

JULIAN HUXLEY, *Discovery*, Vol. VI, p. 365 (*cf.* Vol. III, p. 114).

Special Questions

1. If the hypothesis of the preceding example, namely, that the earth is a solid mass of iron-nickel alloy, is true, what about Wegener's hypothesis? Are these two hypotheses compatible? Upon what assumption about the center of the earth does Wegener's theory rest?
2. Does the fact that Wegener's hypothesis would have the two consequences mentioned at the end of the example make it a more plausible hypothesis?
3. Compare this example with number 7 in Chapter II for proof that changes of climate have taken place. What explanation of this change seems to you to be suggested there?

9. Joly's Hypothesis as to the Nature of the Earth

Recent conclusions of Professor Joly may have important bearings on Wegener's hypothesis. Briefly, he points out that, owing to the radio-activity of the materials of which the central mass of our globe is composed, its internal temperature must gradually rise until the central mass liquefies. This will give the signal for great volcanic upheavals, together, of course, with cooling; and so great cycles or, as he styles them, revolutions, of alternate accumulation and liberation of heat, alternate quiet and volcanic activity, alternate solidity and fluidity of an interior layer of basalt, will constantly recur in the earth's history.

The specific gravity of the basalt on which the continents float alters on the passage from the solid to the fluid state; with such change the floating continents must rise or fall, like icebergs passing from fresh to salt water; and so are explained the alternate floodings of the continental margins with sea and their risings-up once more into the air, which characterize geological history.

Further, Joly points out that solidification and contraction will

produce crumplings of the earth's crust, while liquefaction and consequent expansion will produce tension, and therefore splits and rifts in the continental masses; and further, these, once the underlying basalt is liquefied, must "wander" under the influence of tidal forces.

Here, then, we have the conditions for Wegener's moving continents; however, the conditions are not permanent, but recur cyclically. Thus we should not be surprised if we do not now find the westward movement of America postulated by Wegener, since the continents may at the moment have been "frozen in," like a ship in the Arctic—reduced to immobility by the solidification of the medium which supports them.

Idem, p. 367.

Special Questions

1. Explain how Joly's hypothesis supports Wegener's.
2. How does Joly's hypothesis square with the one in example number 7 in this chapter?

10. Gondwanaland

One of the most fruitful applications of Wegener's ideas has been to the hypothesis, erected by botanists to explain certain facts of the distribution of plants in the past, of the existence up to Mesozoic times of a continent, dignified by the name of *Gondwanaland* connecting South Africa, South America, the Falklands, Antarctica (Scott found the characteristic fossil plants up to 85 degrees S.), Southern India and Australia. It is extremely hard, on known geophysical principles, to explain how the major part of such a vast continental mass could disappear and its place be taken by deep ocean.

Further, traces of glaciation dating from the end of the Paleozoic period have been found in nearly all of these regions. If the ice had covered all the countries as they now lie, together with the intervening region, it would have constituted a glaciation of unparalleled extent, covering the better part of a hemisphere. But this very real difficulty would be overcome if we suppose, with Wegener, that no continental mass has sunk beneath the sea, but that the hypothetical Gondwanaland consisted solely of those parts of the existing continents where the typical fossils are found—which, however were then joined together into a single land mass (and have since split away and drifted to the positions they now occupy).

Idem.

11. No "Lost Continent" in Pacific Ocean

"Lemuria," "Mu," and all the other hypothetical vast land areas forming "lost" Pacific continents, like the lost Atlantis of ancient European imagination, receive no credence on the part of Dr. Francis Xavier Schaffer, noted geologist of Vienna, now traveling in the Pacific area and the Orient. Dr. Schaffer is backed up in his opinions also by the scientists at the Bernice P. Bishop Museum of Honolulu.

Though no land areas of continental size ever existed in the Pacific, Dr. Schaffer stated, there are regions or movable zones where emergence and submergence are constantly in progress.

"Such a line," he said, "goes all around the Pacific and connects the Antarctic continent with the continents of the southern hemisphere. It is easy, too, to see that the northern continents may more than once have been connected by way of the Bering strait and by the rising of the relatively shallow sea bottom between Greenland and Europe."

Dr. Herbert E. Gregory, director of the Bishop Museum, disagrees with the theory advanced by Dr. J. Macmillan Brown, chancellor of the University of New Zealand, who claims that the Pacific islands are the remnants of a once great empire that collapsed into the ocean in a series of cataclysms.

"Geological evidence," said Dr. Gregory, "gives no proof that there ever was a large area of land in the central Pacific. No rock has been found which could be considered part of an old continent. The only way that geologists will ever be able to make a real test of these theories will be by an extensive system of borings which must extend through the coral and the comparatively new levels of the islands, and also by a carefully planned sounding of the Pacific Ocean."

"The lost continent theory cannot be substantiated by botanical discoveries," said Dr. Forest B. H. Brown, botanist of the Bishop Museum. "In the Hawaiian Islands, for instance, over 80 per cent of the plants with net-veined leaves occur nowhere else in the world. Had Hawaii been a part of a continent of which the other Pacific Islands were also parts, one would expect more plants in common to all."

Daily Science News Bulletin, No. 243C.

Special Questions

1. What hypothesis does Dr. Schaffer offer as a substitute for the lost continent hypothesis? How does it compare with the substitute

suggested for the lost continent known as Gondwanaland in the South Atlantic?

2. Why are the geologists and biologists opposed to the lost continent hypothesis?

12. Bacteria and Epidemics

Several years ago Dr. Erwin Smith, of Washington, announced his belief that some varieties of bacteria could exist in several different forms, forms which would be identified by most bacteriologists as totally different species. We now know that this often happens. It is not impossible, even, that some of the disease germs may be merely variant strains of common and supposedly harmless bacteria. They have gone wrong, somehow, and attacked mankind.

Is something like this at the root of the mysterious recurrence of epidemics after a period of years? Dr. Falk, of the University of Chicago, has been writing, for example, about the mysteries of plague, of tuberculosis, of influenza. There were influenza epidemics in 1557, 1729, 1824, 1889 and, as we remember only too well, in 1918. Between these years of almost explosive germ activity the amount of influenza was small.

Why? Is there an occasional change in the germ, so that a bacterium that is always with us and seldom dangerous, becomes suddenly virulent? Or is it something in the varying climatic conditions of the earth? No one knows the answer yet. We need more work on the fundamental nature of the bacteria,—all kinds of bacteria,—and on the changes which they undergo.

Forum, Vol. LXXIV, illustrated section, p. v.

Special Question

Can you suggest any other possible explanations of epidemics besides the two implied in the two questions of the last paragraph?

13. Emulsion Mysteries in Photography

The line along which chemical research is proceeding at present in photography is that of increasing the sensitivity of the plate to the shorter range. What is the secret of sensitiveness of silver salts?

The starting-point in a sensitive emulsion is to mix silver nitrate with a gelatinous solution of ammonium bromide; the precipitate of silver bromide is produced in the form of minute grains or clumps of grains of silver salt, each of which is "clothed" with gela-

tine; this emulsion—really a suspension of silver bromide in gelatine—is excessively insensitive, even though a considerable amount of ammonia be used, as is the case where a rapid emulsion is ultimately required. But a process of "digestion" of the emulsion, at a temperature of something over 35 degrees Centigrade, causes the crystalline grains of silver bromide to grow in size and simultaneously to gain increased sensitivity.

The emulsion, as is well known, is set until jellied, and the jelly is broken up into shreds which are washed with water until the free ammonia and the deliquescent ammonium nitrate by-product is removed. The washed shreds, if remelted and again warmed, again increase in sensitivity until a maximum is reached. The reason for this maximum limit we do not altogether understand. . . .

That the speed of a plate depends solely upon the size to which the grains or crystals grow is now fully disproved. It is evident that some chemical action takes place alongside of the physical modification, and it seems fairly certain that the extreme instability in light of highly sensitive silver bromide is largely due to the presence of "impurities," without which great rapidity cannot be obtained. Not only the sensitivity of the grains but even their spectra absorption can be modified by the absorption of, or interaction with, very minute traces of inorganic matter.

Some attention is being focused just now upon the hypothesis of Fajans and Frankenburger, who think that in sensitizing silver bromide crystals we cause them to absorb hydroxyl ions, and that their sensitiveness is more or less a function of the number of hydroxyl ions absorbed per unit of surface.

Adapted from *Discovery*, Vol. VI, p. 4.

14. The Value of Multiple Working Hypotheses

From the point of view of conserving energy and solving as many problems as possible within a given period, it is undoubtedly the best plan to spend a great deal of time first upon continued general simple observational work, instead of immediately embarking upon detailed and time-absorbing attempts to solve particular individual problems upon the basis of merely preliminary hypotheses. In doing this simple observational work many problems automatically solve themselves, or become solved, by means of the subsequent general observations; whereas if one had attempted to solve these problems at the start by means of a detailed *direct* attack upon them, the subsequent observations show that the original attack would

probably have been upon quite wrong lines, that a very great deal of time would have been wasted, and that probably no results of value would have accrued. Two examples of this highly important fact will now be given.

1. When the writer first began the work in Breckland he thought of analysing many samples of the soils under the heather, sand-sedge and grass-heath associations upon the conventional view that the differences in the vegetation were caused by differences in the soils. These analyses would have taken a great deal of time and various differences in the water-contents, etc., of the different soils would undoubtedly have been detected, but the time would have been wasted. Continued and apparently irrelevant observational work ultimately showed that these differences in the water-contents would have been chiefly due to the occupation of the various areas by different kinds of vegetation owing to the variation in the intensity of the rabbit attack in different places, instead of differences in the vegetation being due to differences in the soils.

2. The writer found an extremely pretty instance of a biotic barrier (i.e., a barrier caused by living organisms) to the spread of a species. This was a case in which sand-sedge, spreading rapidly by means of its underground rhizomes, was stopped abruptly by a row of pine trees several yards from the tree trunks whenever the row was fairly continuous; but that the sedge approached narrow gaps between the pines, and wherever any gap was wide enough, the sedge streamed vigorously through. It seemed that this phenomenon, in addition to being so striking, might also possibly have a bearing upon the important question of the relation of a grassland type to forest, and the writer spent a lot of time trying to find out why the sedge was stopped. Many light-intensity determinations along the limiting edge were made in case it might be caused by shading from the trees. The writer also thought of determining the water content of the soil in different places in case drying of the ground by the trees might be the cause. When he thought of the superior experimental method, he thought of arranging water drips along the limiting edge in order to see what happened; but all these ideas fortunately came to naught, at this stage, owing to the pressure of other problems waiting to be solved. It is too long a story to give here; but, through travelling about Breckland in an attempt to solve other problems, the writer eventually found that the stoppage of the sedge was due to the fallen pine needles and cones, though one would never think this from inspection of the

original site, owing to this deposit being mixed with so much wind-blown sand. . . .

E. Pickworth Farrow in *Discovery*, Vol. VI, p. 350.

Special Questions

1. Explain why the author thinks that it is a mistake for an investigator to begin the work of verifying hypotheses too soon.
2. What advantage is gained by making as many working hypotheses as possible before proceeding with the work of verification?

15. New Light on the Origin of Life

Was the first living being a plant or animal? How could either originate out of a non-living matter?

These are questions that have hitherto baffled scientists. They could trace back, more or less satisfactorily, the lines of development of plants and animals to the simplest and most primitive forms of life, but there they ran up against an insurmountable wall, on the near side of which was the world of living organisms and on the far side the world of inert mineral and inorganic matter.

We all know that non-living matter can be converted over into living matter for we do that ourselves whenever we eat or breathe. We all know that green plants have the power of building up sugar and starch and wood (the so-called carbohydrates) out of the water of the soil and carbon dioxide of the air, for we can see them do it any sunny day. But it is life only that can bring into the living organism this inorganic material. Water and carbon dioxide, which is plain "soda-water," does not spontaneously change over into sugar or start to grow into a plant. It requires green colored granules of the leaves, called chlorophyl, to effect this transformation.

But chlorophyl is a very complicated chemical compound. It is formed only by green plants as they develop in the sun's rays from white sprouts. So the plant must exist before chlorophyl is formed. But on the other hand a plant could not exist unless it got its energy from the sugar and other stuff stored up previously by some chlorophyl-bearing plant. Even the simplest green plant cannot live and grow on its nutritive salts in the sunshine unless it has a bit of plant-stuff to feed on as a starter.

We might surmise as a way out of the dilemma that animal life came first on the earth and in decaying supplied the primitive plants with the necessary organic food-stuff. But here we are blocked because animals are parasites of plants. They live on the sugars and

so forth that the green leaves have stored up by means of sunshine.

So this was the perplexing situation. Plants can feed on animals or other plants. Animals can feed on plants or other animals. But where could the first animals or plants get their food when there was nothing but mineral matter in the world? It was worse than the old question: which came first, the hen or the egg?

But of late we are beginning to get light on the problem. The wall between the living and non-living is crumbling down. Certain sugars and proteins, such as the plant forms that we eat, can now be made in the laboratory out of inorganic material. Artificial cells have been constructed that grow and crawl and feed themselves and stick out feelers and subdivide very much like living cells. It has been found that ultra-violet rays, that is, light of such short waves that it cannot be seen, can convert water and carbon dioxide into sugar as chlorophyl does.

Such short waves are not contained in the sunshine that reaches the earth to-day, but it is found that ordinary rays may act the same way in the presence of certain substances such as iron-rust in water. These energetic rays are also able to incorporate the nitrogen of mineral salts into compounds like the protein of the living cell. So here we see the possibility that the action of the sunlight on the sea in primordial periods—or even in the present—might produce sufficient food to give a single cell a start in life and enable it to grow and multiply and develop into other higher forms.

But how this primal cell got to going in this way the biologists are only beginning to surmise. Dr. E. J. Allen at the Hull meeting of the British Association for the Advancement of Science ventured the theory that the first organism was of the animal sort and spherical shape but that it gradually grew a tail or whip that enabled it to rise to the sunny surface of the sea whenever it sank below, and that it there acquired the chlorophyl by which it could make its own food out of the air and water. This is far from knowing what did happen in those early days, but it is a great advance to be able even to speculate as to how it might have happened, since not many years ago it seemed that it could not happen at all.

The old question of spontaneous generation has taken on a new aspect from the discovery in recent years of organisms too minute to be discerned by the most powerful microscopes. They may pass through porcelain filters that will catch ordinary bacteria, and so cannot be so very much greater than the largest protein molecules

known to the chemist. Yet they are capable of infecting animals and plants with certain specific diseases, such as the mosaic diseases that discolor tomato and tobacco leaves. Here chemistry and biology come close together, and the chasm between them may some day be bridged. As Professor Dendy of the University of London says in *Problems of Modern Science:*

"In this more minute realm of the ultramicroscopic organisms or viruses the transition from the inorganic to the organic may conceivably be taking place even at the present time."

So it is evident that some scientists are coming to look upon the origin of life, not as a unique event in the history of the world, occurring under exceptional conditions in the remote past, but as something which might occur or may be occurring to-day.

Edwin E. Slosson, *Chats on Science* (The Century Co.), p. 191.

Special Questions

1. What was the old assumption with which the problem of the origin of life was approached?
2. What is the new assumption?
3. Which do you regard as most fruitful and why?

16. Accommodation

In his *Physiological Optics* Helmholtz deals very fully and clearly with the facts and theories of accommodation. The main facts are: (1) The pupil contracts in accommodation for near vision and dilates for far vision; (2) The pupillary margin of the iris and the centre of the anterior surface of the lens move forward slightly in incipient accommodation for near vision; (3) The anterior and posterior surfaces of the lens become more convex in near vision and less convex for far vision.

Many antagonistic opinions and theories have been entertained concerning the action and mechanism of accommodation. Helmholtz discusses them under the headings:

(1) Theories that deny not only the necessity but also the existence of any change of the optical system of the eye;
(2) Opinions which consider the contraction of the pupil as sufficient to account for accommodation in near vision;
(3) Opinions that involve a change of curvature of the cornea;
(4) The supposition that accommodation is produced by a shifting of the position of the lens;

(5) Hypothesis of change of form of the lens;
(6) The supposition that the form of the eyeball changes.

The author concludes that he sees no reason to modify his own theory as given on p. 151, the main points of which are "In the passive far-seeing state of the eye the lens is stretched by the zonule attached to its edge. On contraction, the ciliary muscle could pull the posterior end of the zonule forward nearer the lens and reduce the tension of the zonule. But the effect of the tense zonule is to exert a pull on the lens along its equatorial diameter, and thus to shorten its axis and make its surface flatter. If the pull of the zonule is relaxed in accommodating for near vision, the equatorial diameter of the lens will diminish and the lens will get thicker in the middle, both surfaces becoming more curved. If the pressure of the iris is superadded, the equatorial plane of the lens will bulge forward, increasing that of the posterior surface, so that the latter may be approximately equal to its original amount when the lens is accommodated for far vision."

Discovery, Vol. VI, p. 465.

Special Questions

1. Under which of the six headings does the author's own hypothesis, as stated in the last paragraph, fall?
2. Explain why it would have been better for the author to use the word hypothesis instead of the word theory throughout this example.

17. Bacteriophage

Bacteriophage, that mysterious principle or organism, as yet unseen by any scientist though used daily by many, has been discovered in a new rôle as devourer of the deadliest of bacteria, by Dr. Paul F. Clark and Alice Shiedt Clark of the University of Wisconsin, and Dr. L. O. Dutton of the Methodist Hospital, Memphis, Tennessee.

The most dangerous of the disease-causing organisms which the three researchers have discovered to be a part of the bill of fare of the bacteriophage is known as the hemolytic streptococcus, or blood-dissolving chain-germ, because of its fatal action in the blood, causing one of the worst types of blood poisoning. It is also the causal organism of scarlet fever, and of one of the deadliest types of pneumonia.

Cultures of this organism in test tubes grow vigorously and make

the nutrient fluid cloudy, but the introduction of a little material containing the bacteriophage soon makes it clear again, due to the death and disintegration of the disease germs. In Dr. Dutton's experiments, this clearing-up of the cultures took place in as short a time as thirty-six hours.

Bacteriophage, which literally translated means "bacterium eater," is a puzzling something discovered by the researches of F. W. Twort, a British scientist, and F. d'Herelle, a French Canadian. Bacteriologists are very much at odds over it, some claiming that it is a living organism, or at least a living substance, and others maintaining that though it does some things that living beings do it does not have all the attributes of life.

If it has an organized body at all it must be exceedingly minute, for it has never been seen even with the ultra-microscope, and it can pass through the pores of a fine porcelain filter. Moreover, it is not killed by high temperatures that are fatal to all other known organisms. Yet when even a little of the fluid containing it is added to a culture of bacteria, the latter are soon dead, no matter how numerous they are nor how little there was of the bacteriophage to begin with.

It is this apparent power to multiply itself that sets the bacteriophage apart from even the most complex of lifeless chemicals, for lifeless things do not have the power of self-propagation. Much research of this puzzling stuff is now in progress, from which far-reaching effects in medicine and sanitation may result.[1]

Daily Science News Bulletin, No. 261A (*cf. Discovery,* Vol. II, p. 182).

18. The Relation of Ontogeny to Phylogeny

The Theory of Recapitulation regards the development of the individual as an abbreviated and a more or less distorted replica of the development of the race. The theory assumes that every individual passes through all the stages of development through which his species has previously passed. This is taken to be an immanent law of development based upon inherited dispositions. . . .

The theory has many advocates, among whom Stanley Hall and his school have taken the greatest pains to formulate it in demonstrable terms. Their method is essentially this: to analyse modes of behaviour of the most general sort, and to point out those fea-

[1] It is interesting to note that Sinclair Lewis, the novelist, refers to bacteriophage in *Arrowsmith.*

tures which can not be explained as a product of learning or individual acquisition, but which may be found nevertheless in quite similar forms at earlier stages of development. In this way Stanley Hall has investigated the phenomenon of fear. As an instance, he takes the inexplicable *pavor nocturnus*—the fact that children often awake and cry out in the night with a terror from which it is hard to get them back to sleep again—which he explains as an atavism. The child reverts to a long-past epoch when man slept alone in the woods, exposed to danger, and was suddenly disturbed in his sleep. . . .

Instead of regarding individual development as a repetition of racial development, the Theory of Utility attributes both to the same causes. All development is said to result from the operation of two principles: accidental variation and the selection of appropriate responses. In the course of racial development certain types of response arise in accordance with these principles, and either survive or are again lost. If retained in any species, the moment for the appearance of such a trait in the ontogenesis of that species is determined as a joint effect of variation and selection, rather than by the law of recapitulation. For instance, nursing occurs very early in the ontogenesis but very late in phylogenesis. The situation is reversed with respect to the sexual instinct, which appears early in racial development, but late in the development of the individual. This theory, which is vigorously upheld by Thorndike, is based upon the general theory of development associated with the name of Darwin, although Darwin and his immediate school did not restrict themselves within the limits imposed by the "New-Darwinism" which has been named after him, and which employs only the two principles of variation and selection. . . .

The third of these theories of development, which is known as the Theory of Correspondence, maintains that ontogenesis and phylogenesis are closely related processes. Since each has to do with the development of organisms, it is highly probable that certain general characteristics of development play a dominant part both in ontogenesis and in phylogenesis. In the concrete terms of Claparede, "Nature employs identical means for effecting the evolution both of the individual and of the race." One may expect, therefore, that all the beginning stages in any course of evolution will actually be of a similar nature, and that this similarity will apply equally to primitive levels, to more progressive levels, and even to the highest levels of development. Dewey and his school

have elaborated this theory for child-study, and a similar idea underlies Oswald Spengler's *Philosophy of History*. . . .

If we must declare ourselves with respect to these three theories, it is at once obvious that the third theory is far more cautious than either of the other two; its hypothesis being closer to the factual data, the way is left open to further theoretical constructions. This is a great advantage, because in general the current theories of development, and especially those of inheritance, are highly controversial and unsatisfactory. The third theory relieves us from the necessity of deciding for any one theory—a decision which at best would be arbitrary—and it thereby holds our interest in the discovery of further explanations of the facts. After investigations undertaken from this point of view have yielded concrete results, we can readily use them in the construction of further hypotheses.

KURT KOFFKA, *The Growth of the Mind,* translated by R. M. Ogden (Harcourt, Brace & Co.), pp. 44-48.

Special Questions

1. State the assumption or assumptions underlying each of the three theories or hypotheses.
2. Why does the author prefer Dewey's hypothesis to that of either Hall or Thorndike? Do his reasons seem to you to be good?

CHAPTER VIII

VERIFICATION AND THE COMPLETE METHOD OF EXPLANATION

The requirements of a good hypothesis are that it must be simple, conceivable and not absurd, and such that deductions can be made from it which are susceptible of being tested. The making and the testing of deductions is *verification.* If the evidence obtained in the tests proves the deductions the hypothesis is said to be verified *positively,* but if the deductions are disproven the hypothesis is said to be verified *negatively.* Thus hypotheses are usually verified indirectly, that is to say, by verifying the deductions.

Each hypothesis can be regarded as the antecedent of an hypothetical proposition, the consequents of which are the deductions. This means that it takes the form: If hypothesis W is true, then x or y or z follows. Verifying positively consists in showing that x or y or z follows, and the conclusion is that the hypothesis is probably true. Note that the conclusion is only probably true because positive verification commits the technical fallacy of the hypothetical syllogism known as *affirming the consequent.* Negative verification, however, since it shows that the deduction is false, that is, *denies the consequent,* yields the valid conclusion that the hypothesis is false. (See above, page 5, or Robinson's *Principles of Reasoning,* Chapter XII, or the chapter on the hypothetical syllogism in any textbook of logic.)

There are various ways of verifying, the most important of which are:

1. *Observation and Experimentation.*—This involves making a detailed study of the data on hand, gathering more data, or performing an experiment of some kind, all with the definite purpose of finding out whether the deduction which is

being tested really holds. In making such tests Mill's methods may be used.

2. *Mathematical Calculation.*—When quantitative matters are involved mathematical calculations may be made and the facts shown to be either consistent or inconsistent with these computations. This way of verifying is frequently combined with experiment or observation, the calculations being regarded as a more exact and detailed interpretation of the deduction. Sometimes such mathematical elaborations of a deduction furnish the basis of a *prediction* of the precise way in which something will happen in nature. When such a theoretical prediction is later verified, the proof of the hypothesis from which it has been deduced is highly conclusive.

3. *Statistical Verification.*—Closely allied to mathematical calculation is statistical enumeration. When experiment is out of the question a statistical study may be made for the purpose of ascertaining whether the deduction always or generally holds. This may also bring into play the method of sampling.

4. *Verification by Elimination.*—An hypothesis may be strengthened by eliminating all competing hypotheses. The negative verification of competing hypotheses becomes a positive verification of the hypothesis which cannot be eliminated. To be sure other evidence can usually be found favoring such hypotheses, but elimination greatly strengthens the remaining hypothesis. Here again, as in Mill's method of difference, negation is shown to be highly significant in the growth of knowledge.

5. *Verification by Disjunctive Reasoning.*—Sometimes the hypothesis is verified by showing that it is the only one consistent with what is already known in the field of knowledge to which the data under investigation belong. The reasoning may take the form of a disjunctive syllogism—either this hypothesis is true or else what we know in this field is false. But what we know in this field is not false and hence this hypothesis is true. Consistency with previous knowledge in its field is always an excellent criterion of the truth of any hypothesis. That is why scientists always try to show that

the hypothesis which they defend fits in with what we know better than any of the competing hypotheses.

In actual research scientists combine, in one way or another, all of these methods of verifying hypotheses. Hence it is a mistake to think of them as being mutually exclusive. The scientist verifies his deductions in any way that he can.

This brings us to the most important general method of reasoning in science. It may be called the *complete* method of explanation or the *synoptic* method because it combines in various ways the methods which have already been discussed. It consists of four chief steps:

1. Collecting the data to solve a given problem or to meet a specific situation.
2. Formulating hypotheses which seem to explain the data.
3. Making deductions from the hypotheses. (When these are not explicitly stated they are implied in the tests.)
4. Verifying the deductions in any of the ways mentioned above.

Usually the last three steps are carried through for a single hypothesis at a time, instead of all the hypotheses being formulated before any deductions are made and tested, but, as was made clear in the preceding chapter, there is a decided advantage in formulating multiple working hypotheses before proceeding to the work of verification. Assumptions of one kind or another more or less control the whole investigation.

WHAT TO READ

John Dewey gives an excellent analysis of a complete act of reflective thinking in *How We Think,* Chapter VI. He distinguishes five steps, but he points out that the first two are usually combined and together they constitute number 1 above. Every student should read this chapter in Dewey's book. The seventh chapter is also very valuable. Real also any one of the following:

Columbia Associates, *An Introduction to Reflective Thinking,* Chap. I.
Creighton, J. E., *An Introductory Logic,* pp. 207-215, 285-297.
Jones, A. L., *Logic, Inductive and Deductive,* Part III, Chap. III.
Joseph, H. W. B., *An Introduction to Logic,* Chap. XXIII. (See the summary on page 521 for the four steps in the complete method.)

MELLONE, S. K., *An Introductory Textbook in Logic,* pp. 326-339.
MCCLURE, M. T., *Introduction to the Logic of Reflection,* Chap. XII on verification and Chaps. XI and XIV on explanation.
ROBINSON, D. S., *The Principles of Reasoning,* Chap. XXIV.
SELLARS, R. W., *Essentials of Logic,* Chap. XXIV.
WALLAS, G., *The Art of Thought,* Chap. IV. (Very suggestive.)
WOLF, A., *Essentials of Scientific Method,* Chap. VII.

WHAT TO DO WITH THE EXAMPLES

1. Analyze each example into the four steps of the complete method of explanation. State each hypothesis and each deduction made from or implied in testing each hypothesis.

2. In giving the fourth step for each separate deduction tell how it is verified, that is, which of the five ways of verifying listed above is used.

3. Tell whether each hypothesis in each example is verified positively or negatively. Note that in several of the examples one or more hypotheses are rejected and one is accepted. But in a few of the examples only one hypothesis is discussed.

4. To what science does each example belong?

Note: Your analysis should follow some such pattern as this: I. Problem stated and data listed. II. Hypothesis No. 1 stated. III. Deduction or deductions from hypothesis No. 1 stated. IV. Evidence for each deduction stated. This deduction being verified either positively or negatively, the hypothesis is either accepted or rejected. State which is true in each case. V. Hypothesis No. 2 stated. VI. Deductions made. VII. Deductions verified, and so on through each hypothesis.

1. A New Cure for Crime

Operations on the skull to remove the cause of crime are unwarranted medical practice, in the opinion of Dr. Shepherd I. Franz, psychologist in the University of California, and expert in the re-education of the damaged brain.

The supposition that a bony protuberance of the cranium or some malformation due to accident may press on the brain and be the specific cause of wrong-doing is rejected by Dr. Franz and relegated to the limbo of phrenology or like pseudo-science. Surgeons of questionable ethical standards, with prospects of a high fee, have been willing to operate on a criminal, the purpose in part being to influence a trial court in the direction of leniency. In some cases of

this sort the patient, profoundly influenced by so serious an operation on himself, has actually been led to believe that the treatment has cured him. Thus purely by suggestion he deserts the criminal life. To this extent only is the cranial operation of any value.

Extended experiments in brain operation have convinced Dr. Franz that the upper brain structure works generally as a whole, and not in specialized departments. Damage or pressure on one spot does not throw any one faculty alone out of commission, nor does any single faculty or sense belong solely to one unique location. Removal or destruction of a small special brain area will seriously upset the entire mental function, but the patient can be re-educated to perform all his duties with other cerebral material.

Daily Science News Bulletin, No. 279B.

2. Cyclones Whirl Life to Distant Pacific Isles

A new idea has been brought to bear on one of the moot questions of the Pacific, the problem of the dispersal of life from island to island of that vast region.

"Is it not probable that tropical cyclones have played a part?" asks Dr. Stephen S. Visher, Yale University-Bishop Museum fellow of 1921-22, whose paper on these Pacific storms has been published by the latter institution.

Agencies of distribution which have hitherto been recognized by two schools of thought are the possibility of either continental or island land masses far greater than those seen in that region today, and the prevailing winds and ocean currents which move westward throughout the area. Yet it has been proved that many of the organisms of even the most eastern islands are related to Asiatic rather than to American forms!

"Along the equator are many violent westerly winds," Dr. Visher states, "completely overcoming the prevailing easterlies; within the tropics or just beyond many storms move westward. In moving east the strong westerly wind on its equatorial side carries much with it and sets up a strong drift as well."

The effects of a single hurricane are small, Dr. Visher says, and heretofore they have been believed to occur only at long intervals. Yet records which he has compiled show more than two score annually, on the average, in the Pacific, and naturally the question of their influence now takes on a different aspect.

"Hurricanes are less likely to be ignored as a factor in the dis-

persal of life," the scientist maintains, "when it is realized that probably more than a billion years have elapsed since life became abundant upon the earth. Hence fortuitous happenings, such as the dispersal of living forms by hurricanes, have had a long time in which to succeed."

Daily Science News Bulletin, No. 259C.

Special Questions

1. What two hypotheses, other than the cyclone hypothesis, are implied in the third paragraph? What deduction from them is disproved in the last sentence of that paragraph?
2. What bearing would the abandonment of the lost continent theory (see above, page 175) have on one of these hypotheses?
3. Does Dr. Visher use the method of sampling in proving his own hypothesis? Does he use mathematical calculation? Give reason for your answer.

3. The Function of the Spleen

Let us review the situation up to the point at which we have arrived.[1] We started with the underlying idea that if the body were deprived of blood by a diversion of that fluid to the skin in a warm climate, the blood volume would increase and the necessary corpuscles might be extruded as an emergency measure from the spleen. We have seen that administration of carbon monoxide which reduces the quantity of oxyhæmoglobin in circulating blood will make the spleen contract, and as mere deficiency of oxygen in the inspired air will do the same we are justified in asking whether the spleen is, in fact, a reserve of red blood corpuscles—a place where, if not wanted for the transport purposes of the body, they may be "parked" till some emergency arises which demands an increased number of vehicles of oxygen transport. . . .

If the spleen is to be regarded as a sort of bank of red blood corpuscles in which they are stored in large numbers and from which they can be thrown into the currency of the circulation on demand, the spleen should respond to two calls which have not yet been considered; of these the first is hæmorrhage, in which oxyhæmoglobin is removed from the circulation; the second is exercise in which the utilisation of the hæmoglobin is much increased. Let us consider first the question of hæmorrhage. Cat 1 was not bled to death in a single bleeding but in a succession of bleedings and under urethane. In this case the urethane had little effect on the size of the spleen,

[1] See above, Chap. III, No. 13 and Chap. V, Nos. 19 and 20.

but on hæmorrhage it contracted down until in the death-agony the spleen was only one-sixth of its original size. After death it expanded somewhat; presumably the muscular fibres relaxed, but in the absence of any considerable circulation the expansion could not be very great.

During the hæmorrhage the spleen of Cat 1 shrank from 24.3 to 4.1 g., squeezing out over 20 g. of material. This material, if blood, would correspond to about one-sixth of the blood volume of the cat; if red blood corpuscles, to about one-third of the corpuscles. Quite similar results were obtained on Cat 2. . . .

With exercise which was not at all severe the spleen can squeeze out 10-17 g. of something which may be blood, or may even be mostly red corpuscles. In the latter case 17 g. of corpuscles would correspond to about 40 c.cm. of blood, or blood equivalent to about one-third of a quarter of the total blood volume of the cat. Similar but less striking results were obtained from rabbits.

The last specific point to which I shall address myself is this. Can it be shown in point of fact that the possession of a spleen really makes any tangible difference to the organism? Well, I suppose the greatest difference which anything can make to it is the difference between life and death. Can we, therefore, think out any set of circumstances in which animals without spleens would die where animals with spleens would, on the whole, survive? Such a circumstance might be a certain degree of hæmorrhage, but more easy of experimental proof is a certain degree of carbon monoxide poisoning. Several experiments were performed in which guinea-pigs of three categories were exposed to coal-gas.

The three categories were: (*a*) normals; (*b*) those in which the abdomen had some omentum or pancreas had been removed in the neighbourhood of the spleen; (*c*) those in which the spleen was removed. In a typical experiment three animals of each category were placed simultaneously in a chamber and the gas tap turned on. The times of death were noted and also the percentage saturation of the blood with carbon monoxide at death. Briefly, it may be said that the fatal percentage of carbon monoxide in the blood of all the guinea-pigs was the same. On the whole the animals in category B died a trifle sooner than those in category A, whilst the splenectomised animals died markedly sooner than either.

Control experiments of another sort were made. The animals were exposed not to carbon monoxide, but to hydrocyanic acid—a gas which does not poison by making a demand on the hæmoglobin

in circulation. In this case no difference could be detected between the longevity of the normal guinea-pigs and that of the controls in the hydrocyanic acid.

JOSEPH BARCROFT, *The Lancet,* Feb. 14, 1925, pp. 328*f.*

Special Questions

1. How many different illustrations of the use of Mill's methods can you find in this example? How many different methods does he use?
2. Does the last specific point to which he refers indicate a third deduction?

4. Are Odors Chemical or Physical?

Anything we smell must be in a gaseous state, for it has to be carried to the nostrils in the air which we breathe. It may be in the inspired air, as when we smell a perfume, or in the expired air passing from the region of the mouth and throat into the nose, as are the substances which are responsible for the flavour of food and drink, for flavour is not perceived by the sense of taste, but by the sense of smell, as anyone who has had his nose blocked up by a cold will realize. The odorous substance is thus brought into contact with the hairs of the olfactory cells, which are apparently stimulated, and a sensation of smell results. This is agreed, but how does the stimulation occur? Is it chemical, the odorous substance affecting the hairs like a chemical reagent, or is it physical, depending on waves in the air or ether, as in the case of the senses of hearing or sight? Here admitted fact ends, and speculation begins; some people claim that the effect is chemical, and others that it is physical.

We seek in vain for any relation between chemical constitution and smell; although certain substances which are called "aromatics" have both the same odour and a similar chemical constitution, and although certain compounds of arsenic and phosphorus smell of garlic, any relation between chemical composition and odour breaks down completely as we examine it more closely. Artificial and natural musk, for instance, have the same odour, but are chemically utterly different; prussic acid and nitrobenzol smell the same, but are totally unlike in structure. Many other examples could be given of the failure of this suggestion, and we have therefore to seek explanations on other lines.

Impressed by this failure, physiologists have been led to suggest

that the action of odorous substances may be not chemical but physical. The minute particles of which the substances are made up—particles called molecules—are known to be in a state of very rapid vibration, and it is supposed that these rapid movements set up in the surrounding air little waves, just as the movement of a stone sets up ripples on a pond. These tiny waves are then propagated through the air in the nose, and fall on the hairs of the olfactory cells, which are caused to rock to and fro thereby; the movements of the hairs thus set up an impulse in the cell to which they are attached, the impulse is carried to the brain, and there interpreted as a smell. In this way the vibrating molecules act somewhat like a wireless transmitter, and the hairs of the cells like a detector, the principal difference being that the waves, instead of being metres in length, are exceedingly short—shorter, indeed, than the waves of light. Since a molecule of camphor vibrates at a different rate from a molecule of, say, turpentine, each sets up its own particular length of wave; the hairs of the olfactory cells are stimulated in the one case by a wave of a particular length, and in the other by one which is perhaps shorter; in this way it comes about that camphor is recognized as smelling different from turpentine, and in the same way we can have as many different kinds of smell recognized as there are lengths of wave which can be generated and received.

To this theory, too, there are some serious objections, for, if there were not, the sense of smell would not be the mystery it is. According to the theory, prussic acid should smell the same as steam, for the waves generated are identical; of course, they do not smell the same, for one is odourless while the other smells powerfully of almonds. Thus we have still the unsolved problem; the chemical explanation fails us, and the physical explanation fails us too—neither accounts for the facts, and the sense of smell guards its secrets. It may be, of course, that both theories are true in part, or that the exceptions are only apparent exceptions which would disappear if we knew the facts more fully, but so far we have to admit defeat.

ERIC PONDER in *Discovery*, Vol. VII, pp. 106*f*.

5. The Discovery of the Sense of Orientation

I was rounding a sharp railway curve once when I suddenly saw all the trees, houses, and factory chimneys along the track swerve from the vertical and assume a strikingly inclined position. What

had hitherto appeared to me perfectly natural, namely, the fact that we distinguish the vertical so perfectly and sharply from every other direction, now struck me as enigmatical. Why is it that the same direction can now appear vertical to me and now cannot? By what is the vertical distinguished for us?

The rails are raised on the convex or outward side of the track in order to insure the stability of the carriage as against the action of the centrifugal force, the whole being so arranged that the combination of the force of gravity with the centrifugal force of the train shall give rise to a force perpendicular to the plane of the rails.

Let us assume, now, that under all circumstances we somehow sense the direction of the total resultant mass-acceleration whencesoever it may arise as the vertical. Then both the ordinary and the extraordinary phenomena will be alike rendered intelligible.

I was now desirous of putting the view I had reached to a more convenient and exact test than was possible on a railway journey where one has no control over the determining circumstances and cannot alter them at will. I accordingly had a simple apparatus constructed.[1] . . .

Once, while performing one of these experiments, and after rotating so long that I was no longer conscious of the movement, I suddenly caused the apparatus to be stopped, whereupon I immediately felt and saw myself with the whole box rapidly flung round in rotation in the opposite direction, although I knew that the whole apparatus was at rest and every outward point of reference for the perception of motion was wanting. Every one who disbelieves in sensations of movement should be made acquainted with these phenomena. . . .

The sensation of rotation in the opposite direction after the apparatus has been stopped, slowly and gradually ceases. But on accidentally inclining my head once during this occurrence, the axis of apparent rotation was also observed to incline in exactly the same manner both as to direction and as to amount. It is accordingly clear that the acceleration or retardation of rotation is felt. The acceleration operates as a stimulus. The sensation, however, like almost all sensations, though it gradually decreases, lasts perceptibly longer than the stimulus. Hence the long continued ap-

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[1] The author then describes this apparatus. It was a device in which he could have himself rotated in various directions.

parent rotation after the stopping of the apparatus. The organ, however, which causes the persistence of this sensation must have its seat in the *head,* since otherwise the axis of apparent rotation could not assume the same motion as the head.

If I were to say, now, that a light had flashed upon me in making these last observations, the expression would be a feeble one. I ought to say I experienced a perfect illumination. My juvenile experiences of vertigo occurred to me. I remembered Flourens's experiments relative to the section of the semi-circular canals of the labyrinths of doves and rabbits, where this inquirer had observed phenomena similar to vertigo, but which he preferred to interpret, from his bias to the acoustic theory of the labyrinth, as the expression of painful auditive disturbances. I saw that Goltz had nearly but not quite hit the bull's eye with his theory of the semi-circular canals. This inquirer, who, from his happy habit of following his own natural thoughts without regard for tradition, has cleared up so much in science, spoke, as early as 1870, on the ground of experiments, as follows: "It is uncertain whether the semi-circular canals are auditive organs or not. In any event they form an apparatus which serves for the preservation of equilibrium. They are, so to speak, the sense-organs of equilibrium of the head and indirectly of the whole body." I remembered the galvanic dizziness which had been observed by Ritter and Purkinje on the passage of a current through the head, when the persons experimented upon imagined they were falling towards the cathode. The experiment was immediately repeated, and some time later (1874) I was enabled to demonstrate the same objectively with fishes, all of which placed themselves sidewise and in the same direction in the field of the current as if at command. Muller's doctrine of specific energies now appeared to me to bring all these new and old observations into a simple, connected unity.

Let us picture to ourselves the labyrinth of the ear with its three semi-circular canals lying in three mutually perpendicular planes, the mysterious position of which inquirers have endeavored to explain in every possible and impossible way. Let us conceive the nerves of the ampullæ, or the dilated extensions of the semi-circular canals, equipped with a capacity for responding to every imaginable stimulus with a sensation of rotation just as the nerves of the retina of the eye when excited by pressures, by electrical or chemical stimuli always respond with the sensation of light; let us picture to ourselves, further, that the usual excitation of the

ampullæ nerves is produced by the inertia of the contents of the semi-circular canals, which contents on suitable rotations in the plane of the semi-circular canal are left behind in the motion, or at least have a tendency to remain behind and consequently exert a pressure. It will be seen that on this supposition all the single facts which without the theory appear as so many different individual phenomena, became from this single point of view clear and intelligible.

I had the satisfaction, immediately after the communication in which I set forth this idea, of seeing a paper by Breuer appear in which this author had arrived by entirely different methods at results that agreed in all essential points with my own. A few weeks later appeared the researches of Crum Brown of Edinburgh, whose methods were even still nearer mine. Breuer's paper was far richer in physiological respects than mine, and he had particularly gone into greater detail in his investigation of the collateral effects of the reflex motions and orientations of the eyes in the phenomena under consideration. In addition certain experiments which I had suggested in my paper as a test of the correctness of the view in question had already been performed by Breuer. Breuer has also rendered services of the highest order in the further elaboration of this field.

ERNST MACH, *Popular Scientific Lectures* (Open Court Publishing Co.), pp. 286*f*.

Special Questions

1. What is the relation of the hypothesis that the sense of orientation has its seat in the head to the hypothesis stated in the third paragraph?
2. How many different experiments does Mach mention to verify the second hypothesis?
3. How is the second hypothesis made more definite in next to the last paragraph?
4. What is the significance of the facts mentioned in the last paragraph (Breuer and Crum Brown)?

6. Gorilla's Strength Due to Pituitary?

It is possible that the pituitary gland is responsible for the difference between men and gorillas.

The gorilla is, from the point of view of the structure of his anatomy, man's nearest relative. Contrasting man and his ape cousin in a lecture recently given before the Royal College of Sur-

geons, Sir Arthur Keith, M.D., F.R.S., said that man has stayed in a state of physical development corresponding to a gorilla's youth. In his evolutionary career man has moved in the direction of brain while his next anthropoid neighbor has progressed in the direction of brawn.

About forty or fifty years ago, he stated, when cases of abnormal growth were just beginning to be studied, some observers were struck with the fact that patients suffering from such a malady, now known in medical parlance as acromegaly, underwent changes similar to those occurring in the maturing phases of a gorilla. There was an immediate inclination to explain such phenomena as an evolutionary reversion to an ancestral state now represented in the bodies of gorillas, really back to the ape stuff, in short.

Sir Arthur says of this explanation:

"It seems more legitimate, in the present state of our knowledge of the action of hormones on the growth of the body, to regard gorilla characters, whether they occur as a normal manifestation in the life-history of the gorilla or as an abnormal manifestation in the life-history of the acromegalic, as being due to an increased action of that element of the pituitary gland which influences the processes of growth."

This argument has been opposed on the ground that the gorilla does not possess an unusually large pituitary gland, but this contention is refuted by calling attention to the obvious complexity of that body which produces many substances the influence of which cannot be determined "by the crude use of scales or microscope."

Careful study of abnormal growth cases shows the influence of the pituitary gland on the growth of the muscular, bony and alimentary systems, just the systems which undergo so great a degree of increase during the later states of the development of the gorilla.

"We may therefore legitimately infer," concludes Sir Arthur, "that, in the evolution of the gorilla, the pituitary has played a prepotent part. The evidence, as it stands, is enough to justify the student of man and ape in believing that he has obtained a real glimpse into the machinery of evolution."

Daily Science News Bulletin, No. 261D.

Special Questions

1. How does the old theory of acromegaly differ from the new hypothesis of Sir Arthur Keith?

2. Why does the new theory better fit the present state of our knowledge of glands?
3. Is Sir Arthur's answer to his opponents fair? Does he refute the old hypothesis?
4. Is he justified in drawing the inference stated in the last paragraph?

7. Claims New Serum Protects from Tuberculosis

Has an old village doctor of Spain, who rose to spasmodic fame by his discovery of an anti-cholera serum, but sidled back to obscurity, repeated his odd feat of forty years ago, and given mankind a weapon against another scourge, tuberculosis?

Dr. Ferran, of Barcelona, discoverer of a vaccine protecting against Asiatic cholera, told the Berlin Medical Association during his recent visit there, of the new serum which he makes from a harmless germ and which he says gives immunity against tuberculosis. His serum is to be tried out in Berlin, and his claim either proved or disproved.

Wholesale vaccination in a children's hospital in Buenos Aires proved the effectiveness of the vaccine, Dr. Ferran claimed. The death rate of the children was cut in half in a year, and no deaths resulted from tuberculosis.

The novelty of Dr. Ferran's theory is his claim that the tubercle bacillus is not one definite kind of an organism, but that it is a regular Dr. Jekyll and Mr. Hyde sort. It changes back and forth between a comparatively harmless type, like those found in decaying matter, and the virulent sort that causes active tuberculosis. The conditions of the body determine which road the organism shall take.

Dr. Ferran succeeded in bringing up virulent tubercle bacilli in his laboratory in such a way that they lost their dangerous ways and became harmless. He also succeeded in doing the reverse, and showed that the virulent tubercle could come from good beginnings. Tests on animals showed that the good could become bad within the body.

Just as his anti-cholera serum claims were considered highly improbable forty years ago, so his claims for the anti-tuberculosis serum are considered today by many medical authorities.

The protective serum is made from the harmless twin but Dr. Ferran claims it protects against the virulent one, and prevents the metamorphosis of the good into the bad.

Daily Science News Bulletin, No. 246D.

Special Question

Does the example given on page 128 contain evidence in support of Dr. Ferran's hypothesis? Why do you think so? See also page 176.

8. The Origin of Petroleum

There are various petroleum deposits in the world and three different explanations of their origin have been suggested. The mineral hypothesis holds that they were produced by an interaction of volcanic steam with certain carbides, resulting in the various hydrocarbons composing oil deposits. Another suggestion is that the oil is the result of fish remains. But in recent years the vegetable hypothesis has been gaining ground. According to this hypothesis oil is the result of a change in the immense deposits of vegetation under the earth caused by heat and pressure. A certain kind of slime known as *sapropel* is formed by the decomposition of vegetable matter. Recently some of this sapropel has been discovered in a semi-bitumenized state, which on distillation gave virtually every distillate usually associated with petroleum deposits. Moreover, the tarry residue from this distillation is similar to that remaining after the distillation of petroleum. Thus the evidence in favor of the vegetable theory of the origin of petroleum appears very strong indeed. It is interesting to note that Pontoine many years ago suggested that this slime formed at the bottom of lakes was a possible origin of petroleum.

A. S. Wilson-Jones in *Discovery*, Vol. V, p. 87.

Special Question

Can you suggest any deductions that might be made from the first two hypotheses which might be used to verify them?

The following is a résumé of the account, written by Fernando Columbus, son of the great explorer, of the data on which Columbus's plan of discovery was founded.

9. The Discovery of America

As this statement was formed from notes and documents found among his father's papers, it is too curious and interesting not to deserve particular mention. In this memorandum he arranged the foundation of his father's theory under three heads: 1. The nature

of things. 2. The authority of learned writers. 3. The reports of navigators.

Under the first head he set down as a fundamental principle that the earth was a terraqueous sphere or globe, which might be travelled round from east to west, and that men stood foot to foot when on opposite points. The circumference from east to west, at the equator, Columbus divided, according to Ptolemy, into twenty-four hours of fifteen degrees each, making three hundred and sixty degrees. Of these he imagined, comparing the globe of Ptolemy with the earlier map of Marinus of Tyre, that fifteen hours had been known to the ancients, extending from the straits of Gibraltar, or rather from the Canary Islands, to the city of Thinæ in Asia, a place set down as at the eastern limits of the known world. The Portuguese had advanced the western frontier one hour more by the discovery of the Azores and Cape Verde Islands. There remained, then, according to the estimation of Columbus, eight hours, or one third of the circumference of the earth, unknown and unexplored. This space might, in a great measure, be filled up by the eastern regions of Asia, which might extend so far as nearly to surround the globe, and to approach the western shores of Europe and Africa. The tract of ocean intervening between these countries, he observes, would be less than might at first be supposed, if the opinion of Alfraganus, the Arabian, were admitted, who, by diminishing the size of the degrees, gave to the earth a smaller circumference than did other cosmographers, a theory to which Columbus seems at times to have given faith. Granting these premises, it was manifest that, by pursuing a direct course from east to west, a navigator would arrive at the extremity of Asia and discover any intervening land.

Under the second head are named the authors whose writings had weight in convincing him that the intervening ocean could be but of moderate expanse and easy to be traversed. Among these he cites the opinion of Aristotle, Seneca, and Pliny, that one might pass from Cadiz to the Indies in a few days; of Strabo also, who observes that the ocean surrounds the earth, bathing on the east the shores of India; on the west, the coasts of Spain and Mauritania; so that it is easy to navigate from one to the other on the same parallel.

In corroboration of the idea that Asia, or, as he always terms it, India, stretched far to the east, so as to occupy the greater part of the unexplored space, the narratives are cited of Marco Polo

and John Mandeville. These travellers had visited, in the thirteenth and fourteenth centuries, the remote parts of Asia, far beyond the regions laid down by Ptolemy; and their accounts of the extent of that continent to the eastward had a great effect in convincing Columbus that a voyage to the west, of no long duration, would bring him to its shores, or to the extensive and wealthy islands which lie adjacent. The information concerning Marco Polo is probably derived from Paulo Toscanelli, a celebrated doctor of Florence, already mentioned, with whom Columbus corresponded in 1474, and who transmitted to him a copy of a letter which he had previously written to Fernando Martinez, a learned canon of Lisbon. This letter maintains the facility of arriving at India by a western course, asserting the distance to be but four thousand miles, in a direct line from Lisbon to the province of Mangi, near Cathay, since determined to be the northern coast of China. Of this country he gives a magnificent description, drawn from the work of Marco Polo. He adds that in the route lay the islands of Antilla and Cipango, distant from each other only two hundred and twenty-five leagues, abounding in riches and offering convenient places for ships to touch at and obtain supplies on the voyage.

Under the third head are enumerated various indications of land in the west, which had floated to the shores of the known world. It is curious to observe how, when once the mind of Columbus had become heated in the inquiry, it attracted to it every corroborating circumstance, however vague and trivial. He appears to have been particularly attentive to the gleams of information derived from veteran mariners, who had been employed in the recent voyages to the African coasts, and also from the inhabitants of lately discovered islands, placed, in a manner, on the frontier posts of geographical knowledge. All these are carefully noted down among his memorandums, to be collocated with the facts and opinions already stored up in his mind.

Such, for instance, is the circumstance related to him by Martin Vicenti, a pilot in the service of the King of Portugal: That, after sailing four hundred and fifty leagues to the west of Cape St. Vincent, he had taken from the water a piece of carved wood, which had evidently not been labored with an iron instrument. As the winds had drifted it from the west, it might have come from some unknown land in that direction.

Pedro Correo, brother-in-law of Columbus, is likewise cited as having seen, on the island of Porto Santo, a similar piece of wood,

which had drifted from the same quarter. He had heard also, from the King of Portugal, that reeds of an immense size had floated to some of these islands from the west, in the description of which Columbus thought he recognized the immense reeds said by Ptolemy to grow in India.

Information is likewise noted, given him by the inhabitants of the Azores, of trunks of huge pine-trees, of a kind that did not grow upon any of the islands, wafted to their shores by the westerly winds; but especially of the bodies of two dead men, cast upon the island of Flores, whose features differed from those of any known race of people.

To these is added the report of a mariner of the port of St. Mary, who asserted that, in the course of a voyage to Ireland, he had seen land to the west, which the ship's company took for some extreme part of Tartary. Other stories, of a similar kind, are noted, as well as rumors concerning the fancied islands of St. Brandan, and of the Seven Cities, to which, as has already been observed, Columbus gave but little faith.

Such is an abstract of the grounds on which, according to Fernando, his father proceeded from one position to another, until he came to the conclusion that there was undiscovered land in the western part of the ocean, that it was attainable, that it was fertile, and finally, that it was inhabited.

It is evident that several of the facts herein enumerated must have become known to Columbus after he had formed his opinion, and merely served to strengthen it; still, everything that throws any light upon the process of thought, which led to so great an event, is of the highest interest; and the chain of deductions here furnished, though not perhaps the most logical in its concatenation, yet, being extracted from the papers of Columbus himself, remains one of the most interesting documents in the history of the human mind.

WASHINGTON IRVING, *Life of Christopher Columbus,* Chap. V.

Special Questions

1. Assuming the truth of Irving's statement in the last paragraph, distinguish the data used to verify the hypothesis of Columbus from that on which the hypothesis was based.
2. Formulate a deduction for each set of data you think he used in verifying his hypothesis and show how this set of data verifies that deduction.

10. Washed Animal Blood May Save Human Lives

Important experiments on blood transfusion, made by Professor Yourevitch and Mlle. Teleguina of Prague, appear to lead to the conclusion that special human blood donors will no longer be required in cases where transfusion is necessary to save a patient's life. The blood of a sheep or a cow might serve the same purpose, and special preparations of solution could be made in advance, and kept in bottles until required.

It has long been known that the most important point about blood in regard to transfusion is its specificity. That is to say, a rabbit can only be saved by the injection of the blood of another rabbit. If the blood of a different animal is injected into its tissues, it dies immediately. In the case of human beings, blood has been divided into four groups. When an injection has to be made, the blood of the patient has first to be tested to see which group he belongs to. Only rare individuals of the fourth group can give blood to any of the others with beneficial and not dangerous results.

Professor Yourevitch and his woman colleague have opened up an entirely new line of treatment. They separated the red blood corpuscles from the serum by centrifuging methods. They found that the poisonous qualities which on injection have such harmful effects are in the plasma, and that if the separation of "washing" is thoroughly carried out, the red blood corpuscles of an animal of one species can be injected into another without the slightest danger, but, on the contrary, with completely satisfactory results.

Rabbits which had lost an absolutely fatal quantity of blood could be saved by the injection of sheep's blood which would have been highly poisonous to them, provided only the washed red corpuscles were injected.

A rabbit which had received 10 to 15 cubic centimeters of unwashed ox blood died within five or six minutes. Another rabbit was given similar blood which had been partially washed, added to some of its own. After a period of serious prostration, it recovered. But a rabbit which had received only the red blood corpuscles of ox blood, which had been thoroughly washed, recovered completely without any detrimental symptoms.

It is confidently suggested by the investigators that in cases where human blood of the right group is not immediately available for transfusion, blood of any other group would be equally benefi-

cial, provided only the washed red corpuscles were used. They also indicate that in their opinion blood of animals could probably be used in the same manner, if no human blood could be obtained.

It is further stated that a preparation of red blood corpuscles in a salt solution has been kept perfectly in bottles, and that there is no reason why such a preparation could not be made up in a standard manner, and stocked for use according to necessity.

Daily Science News Bulletin, No. 260C.

Special Question

Did the experiments entirely disprove the old hypothesis or did they lead to its modification?

11. Proof That the Sun Is a Variable Star

The sun is a variable star. This central fire of the planetary system does not glow with a steady heat but flickers from day to day and from year to year, and the vagaries of our earthly weather must depend at least partly on the sun's variations. This opinion, which has been supported for many years by Dr. C. G. Abbot of the Smithsonian Institution, finds new support in evidence produced by a new system he has devised for measuring and recording the changes in the energy reaching the earth from the sun.

Dr. Abbot calls attention to the work of H. H. Clayton, who has announced that he finds variations of weather caused by solar changes. But many meterologists have not been convinced that the sun really varies. They fear that the complicated measurements of Dr. Abbot, hindered as they are by the haziness and humidity of the earth's atmosphere, are not conclusive. The variability which he reports, they suggest, may all be due to unavoidable atmospheric sources of error.

Dr. Abbot now announces a very direct test that should settle the question. Although it is impossible to do the measuring from a point outside the atmosphere, yet it is possible to select times when the transparency and other affecting qualities of the air are closely alike, and the sun stands at equal height above the horizon. At such times the solar heating should vary only if the sun does.

Selecting the month of July in the years 1910 to 1920 for his test, he collected results observed on Mount Wilson for all days of practically constant atmospheric conditions. The average monthly values thus selected he compared with those obtained by the usual process and heretofore published. He also compared them with the

average monthly numbers of sun spots. The three curves that express his results run along very closely together. They show that the sun's heating in July 1917, averaged over 2 per cent above that of Julys, 1910 and 1911. Correspondingly, the sun spot numbers were 117 in July, 1917, and only 14 and 3, respectively, in Julys, 1910 and 1911.

Not content with this proof of the reality of long-range solar changes, Dr. Abbott rearranged the measures in a way to test short-interval solar variation. For this purpose he picked out from the new data all the days that gave high values of solar heating, and all of those which gave low ones. The average excess value for fifty-one high days was plus 1.43 per cent and the average defect for fifty-one low days was minus 1.47. The same days, as already published four years ago, indicated on the average plus 0.51 and minus 0.42 per cent, respectively. Thus the days shown above normal by the new method of selecting times of equal atmospheric clearness had already been shown as above normal by the usual process, and vice versa. Of course the range as formerly published could not be so great, because the errors of observation could not be expected to fall the same in the two sets of data. Some days would be high and some low, not because of the sun's condition, but because the small observational errors helped to make them so.

Boston Transcript.

Special Questions

1. In verifying his theory, which of Mill's methods do you think Dr. Abbot used?
2. Did he use sampling?
3. Did he use statistics?
4. Did he fit his theory into previous knowledge?
5. Do you think the evidence is sufficient to prove his theory?

12. Borrowing Oxygen for Hard Work

Our muscles can, and do, "go into debt for oxygen," according to *The Journal of the American Medical Association* (Chicago). In other words, a man may do work that requires far more oxygen than he is able to absorb as he does it. Energy is stored in chemical form and the "debt" is paid by increased intake after the work is over. The old idea that combustion of any kind goes on in the muscle is no longer held. The muscle is purely a chemical machine. This is not the first time that radical revision of the older conceptions of the nature of muscular work has been necessary. One of

the early steps was the abandonment of the idea that proteins or other nitrogenous compounds supply the energy for muscular performance. We read:

"For a long time the transformation of energy in muscular work was assumed to be due to the oxidation of carbohydrate, presumably glucose, in the muscle. Perhaps the most radical change of opinion regarding the process has been the abandonment of the theory that this organ is a combustion engine, and the acceptance of the view that it is a chemical machine in which the energy of motion is derived directly from chemical energy.

"It has become a dictum of the science of nutrition that 'the absorption of oxygen does not cause metabolism, but rather the amount of the metabolism determines the amount of oxygen to be absorbed.' In this connection we have heard of late of the possibility of the body's incurring an oxygen deficit under severe exertion. According to the investigations of Hill and Meyerhof, in particular, the process in muscular contraction does not primarily involve oxidation. The muscle accumulates its energy in a form known as glycogen, which is easily and quickly made available at the instant of contraction by transformation into lactic acid, and this process is immediately followed by a contraction. Afterward, the lactic acid remains to be reconverted into glycogen or oxidized. The amount of lactic acid is a measure of the oxygen debt. This point of view makes it easier to understand how it is possible for a man to take an amount of muscular exercise that requires far more oxygen than can be supplied during the exercise. The oxygen is not used in the process of muscular contraction but afterward during the process of recovery. The muscle is capable of going into debt for oxygen. Henderson and Haggard have recently shown that an oarsman may exert a power which exceeds by 30 to 60 percent. that afforded by the oxygen simultaneously absorbed; he thus draws heavily on his credit; these deficits are repaid by the high rate of oxygen absorption for a time after the work is ended.

"Schneider and Clarke, at the School of Aviation Medicine, Mitchel Field, have observed that the oxidative processes of the body are retarded at low barometric pressures. The interference is accentuated during physical work. The aviation authorities assert that despite the markedly decreased consumption of oxygen during work at a low barometric pressure corresponding to a very high altitude, it is not shown that the oxygen debt of the body is increased by work at the low pressure. Theoretically, they state, the oxygen debt

should be larger. Evidently the body protects itself against an oxygen deficit in the early stages of existence at lowered barometric pressures until various protective devices come into play. The disturbances in the biochemical condition of the body are slowly compensated for, if sufficient time is spent under the new condition to permit the system to reëstablish an equilibrium."

Literary Digest, March 27, 1926, p. 23.

Special Questions

1. Why do the investigators say that "theoretically the oxygen debt should be larger" when men work at low barometric pressure?
2. How is this example connected with number 3 on the function of the spleen?

13. Fermentation and Digestion

Fermentation, the totality of the changes produced in digestible material, was for ages believed to be inscrutably mysterious. It was made the subject of debate between the iatro-mathematicians and the iatro-chemists of the 17th century, but neither school really understood it.

Digestion, the great fermentative process in animals, was confused with putrefaction, with boiling and with the effervescence of gas in chemical operation. Stahl (1660-1734) saw in digestion the direct activity of the soul or *anima* which, he held, permeated every tissue and endowed it with special powers. The chemistry of it all, however, was unknown; the very conception of a ferment, a substance produced by living matter but not itself living, had not as yet emerged from the mental confusion.

Van Helmont (1577-1644), Graff (1641-1672), and Haller (1708-1777) all groped for it, but it was not until the work of De Reaumur about 1750 that any true notion was held as to digestion being a form of fermentation. De Reaumur was the first to obtain gastric juice in an approximately pure state and to attempt digestion with it outside the body. Spallanzani began where De Reaumur left off, and discovered in 1777 that digestion was by no means putrefactive, but was apparently due to some "solvent power" or "active principle of solution" in gastric juice. Then, by degrees, as physiological chemistry improved its methods it obtained finer results, and at last the solvent power or principle of solution in the gastric juice was isolated in 1862 as the white powder, *pepsin*, a name which had been given by Schwann to the "active principle" as far back as

1836. Soon other ferments were either isolated or obtained in solution, and today in our laboratories we store them in glass bottles.

Adapted from D. Fraser Harris, *Discovery*, Vol. IV, p. 186.

14. Artificial Incubation

The use of incubators for the hatching of eggs is by no means as recent an invention as we are apt to think. It is true that artificial incubation in Europe only goes back a matter of just over forty years. But in Egypt, China and Malay, the artificial method has been in successful use for thousands of years. The general opinion is that the Western incubator is far less efficient than the mother hen or the Chinese incubators. Mr. L. B. Atkinson set himself the problem of discovering why this should be the case. In order to solve this he inquired in what ways the conditions inside the various types of incubator differed from those underneath the sitting hen. As a result of his observations he formulated the tentative hypothesis that the air under the incubator is too dry, and that the egg is kept at too uniform a temperature. In the nest of a sitting hen the conditions are quite different. The bottom of the egg is much cooler than the top of it that is immediately underneath the hen. There is, in fact, a difference in temperature of between 14 and 20 degrees Fahrenheit.

In order to imitate the natural conditions, Mr. Atkinson covers the upper surface of the eggs with a very thin sheet of india rubber. When this is done in a hot air type of incubator it is quite easy to get a difference in temperature of 14 degrees Fahrenheit between the top and the bottom of the egg. The rubber sheet serves the further purpose of preventing too rapid evaporation of moisture from the eggs, and of keeping the amounts of moisture and carbonic acid gas round the eggs as near as possible to those which operate in the hen's nest. By using this modified method, an incubator which had given no more than 55 per cent efficiency hatched ninety-five per cent of the fertile eggs.

Adapted from *Discovery*, Vol. VI, p. 190.

15. Fighting Caterpillars with Ants

Albert Pfister, in a late number of *Kosmos* (Stuttgart), speaking of the frightful ravages committed by caterpillars, especially among certain evergreens (*Panolis piniperda*), calls attention to the fact that in the broad pathway of barrenness which marks the highroad

over which the army of caterpillars has passed, one is struck by the fact that a few trees have retained all their green needles, while their surrounding companions have been stripped bare by the hosts of the enemy. One theory of the reason of this was that these special trees secreted some sort of defensive substance. But this idea is of little practical value since it would take a hundred years for the building up of a forest from the seeds of these seemingly resistant trees.

Recent observation has suggested another explanation. "A few trees always remain green in the neighborhood of ant hills. Hence it occurred to Head Forester Schulz in Wirschkowitz to increase the numbers of the forest-dwelling ants systematically. He calculated that it was advisable to have one ant hill per hectare throughout the area of the forest. The red wood-ant (*Formica rufa*) was found to be the best for the purpose in mind. The hills of this insect commonly contain from 100,000 to 500,000 ants and, sometimes, as many as a million. Moreover, they are very voracious and bold in attack."

Whenever these ants find a caterpillar, whether on the ground or on the tree they fly to the attack, kill it and devour it. It is thought that in the summer of 1924 the ants kept great areas of forest free of caterpillars.

Adapted from the *American Review of Reviews,* Vol. LXXIII, p. 107.

Special Question

Why was the first hypothesis suggested impractical and what rule for a good hypothesis did it violate?

16. The Nature of Heavenly Bodies

In the days of ancient Greece, Aristotle taught and Ptolemy of Alexandria perpetuated the fallacy that whereas terrestrial things were composed of four "elements"—earth, air, fire, water—the celestial bodies—sun, moon, planets and stars—were composed of a fifth element, a perfect substance, unchanging and unchangeable, the "quintessence." As long as this idea held sway in the minds of men, a science of astrophysics was impossible. For physics deals essentially with *change*—change of position, change of configuration, change of state, change of energy distribution: change of some kind or there is no physics involved. . . . When Galileo turned his hand-made telescope upon the sun and found upon its surface strange,

dark markings which altered both in shape and position from day to day, he threw down and trampled under foot forever the dogma of the immutable fifth substance. There were changes in the face of the sun, great convulsions which darkened portions of its dazzling surface; there were small satellites which moved round and round Jupiter; there were stars which blazed forth a temporary brilliance—all testified to a great law of change ruling in the heavens as well as upon the earth; and from the moment this was realized a science of astrophysics became *theoretically* possible.

A. Vibert Douglas in *Discovery*, Vol. VII, p. 175.

Special Questions

1. Why was the Aristotelian theory wrong?
2. Why does the author say the new theory made astrophysics theoretically possible? What was necessary to make it practically possible?

17. Night Vision

. . . It is a well-known fact that individuals vary considerably in their ability to see in the dim light of night-time. Some people appear to be almost blind in a night of average darkness in which other folk have no difficulty in finding their way about. It is also common knowledge that wild animals can find their way about at night much more readily than human beings. It is true that in the case of wild animals the sense of sight is assisted by a strong sense of smell. In the case of night owls, however, whose power to see "in the dark" is proverbial, it is sight alone which directs them. . . . Australian horses were employed for night work during the war in Palestine, because they did not suffer from "night blindness."

. . . It requires little knowledge to realize that it is impossible for anyone to see in absolute darkness. Vision is only possible when there is some light. To see in the dark means scientifically to see in a dim light. What we wish to know, therefore, is why some people and some animals see better in dim light than others.

The experiments carried out by Professor Russ and his co-worker do not supply a complete answer to the problem. But they do throw considerable light upon one important factor. They show the extremely important part which is played by the transparency of the media of the eye in affecting nocturnal vision. It is obviously the light that reaches the retina that is alone able to help us to see. But on its way to the retina light has to pass through the cornea—

the watch-glass of the eye—the eye lens, and the aqueous and vitreous humours—the jelly-like substances which form the interior of the eye. Professor Russ was successful in showing that these are never perfectly transparent. They never let through the whole of the light. They are most transparent, however, and let through most light, in the cases of those animals which see best "in the dark."

The experiments which Professor Russ conducted were of a most direct character. In each case experimented upon, a fresh, enucleated eye was prepared by cutting away a small portion of the retina at the back of it, and fitting over the aperture a thin quartz plate which was to serve as a window. The eye was then mounted in front of the slit of a quartz spectrometer, which was used to measure the light which filtered through the eye from a cadmium arc. This includes a considerable range of ultra-violet as well as visible light. As was expected, all the eyes absorbed a good deal of the ultra-violet light. There were, however, outstanding differences between the different eyes examined.

The range and amount of light which reached the back of the eye was least in the case of the human eye—three of which were examined. The range of light which filtered through the eye was greatest in the case of the great eagle owl, the eye of which enabled the whole of the visible spectrum, and a considerable portion of the ultra-violet light, to reach the retina. Next came the eye of the tiger, then that of the lion, and then that of the lioness, whose eye was still much more transparent than a human eye. The eye of an ox was about as transparent as the human eye. A cat's eye was shown closely to resemble that of the tiger. It is clear that the nocturnal animals are endowed with eyes that are transparent to a certain range of ultra-violet light, and this is undoubtedly a valuable aid to night vision.

J. Riley in *Discovery*, Vol. VI, p. 189.

Special Question

Why does the author say the experiments of Professor Russ do not supply a complete answer to the problem? What remains to be explained?

18. The Brownian Movement in Colloidal Solutions

In the course of his microscopic studies, Robert Brown observed that solid particles suspended in water, if of sufficiently small size, are in a state of perpetual agitation, moving hither and thither in an irregular zigzag path. Though his observations were first made

with grains of pollen, he soon proved that life had nothing to do with this motion, for he was able to observe it with finely divided coal, sand and other inanimate objects. Successive workers have proved that this so-called "Brownian movement" is not due to any extraneous cause such as vibration, heating effects, etc., and it is now certain that it is caused by the bombardment of the particles by the invisible molecules of the liquid. It has long been known that these molecules must, at any temperature above the absolute zero, be in perpetual motion, and it is even possible to calculate what is the average kinetic energy of such a molecule. The molecules bombard any body immersed in the liquid, but in the case of comparatively large bodies, the bombardments are so numerous that the impacts on each side will on the average be equal and no motion of the body is produced. With particles which are not very much larger than the molecules themselves, the impacts on each side at any moment will not always balance out; there will be an excess of pressure now on one side, now on another, with the result that the particle is driven about in the regular path which we observe. Mathematicians have calculated what the average velocity of the Brownian movement should be, on this theory, for particles of given sizes, and their predictions have been amply fulfilled by experiment.

D. C. Henry in *Discovery*, Vol. V, p. 35.

Special Question

Would you call this a complete explanation of the Brownian movement? Discuss the strength of the evidence supporting this explanation.

19. Listening to Electrons

The function of the thermionic valve in wireless practice is now fairly familiar to many, though comparatively few pause to make themselves acquainted with the phenomena of the electronic flow. The wireless experimenter knows in a rough-and-ready fashion that when the filament of a valve is heated by means of an electric current, a stream of electrons flows from the filament or cathode to the plate or anode, and that the addition of a third electrode or grid makes it possible to control the flow of electrons by varying the potential of the grid with relation to the filament, and it is known that this procedure produces certain definite results. Beyond this point the average experimenter has little desire to go. . . .

The more advanced investigator is by no means satisfied with

this. He seeks a more intimate and minute knowledge of the complex conditions by which these manifestations are surrounded, and in that aspect of research Dr. A. W. Hull, of the General Electric Company's laboratory at Schenectady, and Dr. N. H. Williams of Michigan University have just recorded a remarkable discovery.

German investigators had put forth the hypothesis that the electrons make a noise when they strike the plate but they were unable to prove it. Dr. Millikan, of the California Institute of Technology, carried the theory of the Schrott effect, as it is called, still further, but not to that of its definite establishment. Dr. Hull and his collaborator brought into use amplifiers giving a sound magnification of the order of 100,000 times, and thus not only found decisive proof of the Schrott effect theory, but were able to measure in this way the charge on the electron with an extremely high degree of accuracy. The electrons impinge like a shower of hailstones on the plate and the investigators declare that the sound of this invisible bombardment is like the noise of Niagara Falls heard at a distance.

We are brought here to a phase of research which verges on the marvelous. Thomson, Rutherford, Lodge and others have enabled us to measure the electron. We know that its mass is so minute that 1,000,000,000,000,000—one thousand million million million million—electrons would have a mass of less than one gramme. . . . Sir Oliver Lodge, condensing modern research into a startlingly bold image, has declared that compared with an atom, an electron would be like a fly in a cathedral. Previous experiments in the General Electric Company laboratory resulted in the movements of atoms becoming audible in a loud speaker. Thus Sir Oliver Lodge's cathedral was made vocal, as it were, and now the "fly" within it has also become audible.

Adapted from JOHN ELPHINSTONE, *Discovery*, Vol. VI, p. 71.

Special Questions

1. What method is used in the last paragraph to make the significance of the discovery clear?
2. What is the relation between this and the preceding example?
3. Why did Millikan fail to establish the theory?

20. The Strangest Star

Imagine a substance four thousand times heavier than lead. A paper weight made of this substance would be too heavy for a dozen men to lift. It would probably go right through the table and on

down to the basement, as a heavy safe would crash through a flimsy house. A rifle bullet made of this substance would weigh over two hundred pounds. Only the strongest men could lift it.

Fortunately there is no such substance on earth. A few years ago scientists would have said that no such substance was probable anywhere in the universe. This is changed now. Not only does such a marvelously heavy substance exist, it is probable that there is a whole world made of it.

This world is a star, a star long known as the faint companion star of Sirius. Sirius is the dog star, the brightest fixed star in the sky. It rises about one o'clock these October mornings, well down in the eastern sky, below the familiar belt and sword of Orion. The Sirius that we see is really the brighter of two companion stars. Sirius is a double star. Long ago astronomers discovered this fact and computed as accurately as they could the orbits in which the companion stars revolve, and the weights, sizes, and other characteristics of the two. The weight of the heavy star came out very high, so tremendously high in proportion to the star's size that the astronomers refused to believe their own figures. It was ridiculous, they said, to imagine the existence of matter thousands of times denser than lead. The calculations must be wrong.

There the matter rested until last year. Professor Eddington, the distinguished astronomer of Cambridge University, then suggested that perhaps these ridiculous calculations were right after all. Atomic theory indicated, he urged, a bare possibility that extremely dense matter like this might be real; not on earth, of course, but under some conditions of temperature and pressure which were at least conceivable in the stars. Now our own Mount Wilson Observatory, in California, has tested this suggestion. Eddington was right. The matter of this strange star, the companion of the brilliant dog star, really is many hundreds of times denser than any kind of matter yet found or produced on earth.

In reporting these Mount Wilson tests, Dr. Walter S. Adams, Director of that Observatory, points out that they provide, also, a new test of the Einstein theory. It is one of the conclusions of this theory that light is affected by gravity. One of the three tests proposed for the theory was the shift of the position of certain red lines in the spectrum of sunlight, due to the fact that the light rays forming these lines had started from the surface of the sun where gravity is much stronger than on earth. On the tremendously heavy

star of the Sirius system this shift ought to be, theoretically, some thirty times greater. Gravity is so much more intense.

To measure this shift of the spectrum lines in light from the tiny star was difficult, but it was accomplished. The expected greater shift was found. So we now have good evidence not only for the essential correctness of the Einstein theory, but also for the reality of a star so heavy that if the average substance of it were made into silver dollars they would weigh nearly a hundred earthly pounds apiece.

Forum, Vol. LXXIV, illustrated section, p. xxvi.

Special Questions

1. What requirement of a good hypothesis were the astronomers following when they refused to believe their own figures?
2. Why is this regarded as good evidence for the Einstein theory?

21. The Eclipse and Einstein

The development of a batch of photographic plates is often awaited with impatience and anxiety. In the case of amateur photography the impatience is manifested by the snap-shotter and the anxiety by his sitters.

But probably never before have so many people in all parts of the world been eager to learn "how the plates turned out" as in the case of those brought back from Australia by Dr. W. W. Campbell, director of the Lick Observatory and president of the University of California.

For these negatives were taken during the eclipse of September 21, 1922, and contained the evidence for or against the Einstein theory of relativity, which has excited the interest of all scientists and, for various reasons, an unexpectedly large proportion of the unscientific public. The less people could understand about it the more eager they were to hear about it.

The man who manifested the least anxiety over the result of the eclipse expedition was perhaps Einstein himself, for, having made up his mind eight years before how the heavenly bodies must behave, he remains serenely indifferent to the efforts of astronomers to find out how they do behave. It followed, as a logical deduction from his theory of the relativity of all measurements of space and time, that a ray of light passing close to the sun would be drawn out of its straight course as though the light were attracted by the presence of such a heavy mass. And since the path of the ray is drawn inward

toward the sun an observer on the earth, looking back up the ray, would see the star as though it were moved outward from the sun. If a photograph of a group of stars taken with the sun in the middle is compared with a photograph of the same group without the sun, the images of the stars in the former case will therefore be seen to have been displaced from their ordinary positions in the sky. The star images nearest the sun will naturally be displaced the most and the others in proportion to their distance. . . . As figured out from Einstein's formula, a ray of starlight just grazing the sun's disk would be deflected to the extent of 1.75 seconds of arc.

Of course the stars cannot be photographed when the sun is shining into the telescope, and so one must wait till the sun is totally shielded from the earth by the moon. The first opportunity to put the Einstein theory to the test was the eclipse of 1919, and even while the war was on British astronomers were preparing expeditions to be sent to Brazil and western Africa to put Einstein to the proof. Professor Eddington of Cambridge, who was in charge of the expeditions, was convinced that his observations confirmed the relativity theory of gravitation. But his best plate contained only seven good star images, and this seemed to conservative scientists rather too slight a foundation to support so revolutionary a theory. Since the experiment could not be repeated until the next eclipse, astronomers and amateurs had to hold their breath for four years or waste it in vain disputes.

But when Professor Campbell explained to the American Philosophical Society of Philadelphia and the National Academy of Sciences in Washington the results of the Crocker Expedition to Australia, there was little ground left for skepticism on this point. Instead of one good plate with seven stars, he had four plates of the eclipse, each showing from sixty-two to eighty-four star images. To compare with these he had four plates of the same stars taken at night before the eclipse. The negatives are seventeen inches square, and it took Dr. Campbell fifty hours of working time to measure with the micrometer the positions of the stars on a single pair of plates. Dr. Trumpler repeated the measurements independently, and neither astronomer could know what the results would be until they were finally figured out. Check plates taken of other stars show that the displacement of the images could not be due to any defects of the telescope or of the sensitive plates.

The final average of all the measurements of all the star images on all the plates gave a deflection for a ray passing at the edge of

sun's disk of 1.72 seconds of arc, almost exactly what Einstein had predicted and twice as great as could be deduced from the Newtonian theory of gravitation. . . .

EDWIN E. SLOSSON, *Chats on Science* (The Century Co.), p. 204.

Special Questions

1. Compare this example with the test of the Einstein theory reported in the last two paragraphs of the preceding example. Are both equally conclusive? If not, which do you think is the stronger and why?
2. Why did scientists refuse to accept the proof offered by Professor Eddington?

22. The Great Dew Pond Myth

There are certain ponds situated on the tops of hills generally in the south of England, which go under the name of "dew ponds," and very widespread is the idea that by some mysterious means they automatically keep themselves filled by absorbing dew. This notion is quite wrong, and therefore the ponds in question are misnamed. . . .

It should be noted that the ponds are always on the hilltops, but why this is so, if they function by dew collection, is not clear, as dew is deposited in valleys also. They are very shallow and of large area, generally merely saucer-shaped depressions in the chalk, and are used for supplying grazing cattle with water. This very large area constitutes a big catchment surface, so that they are well fitted for catching and storing rain or any deposited moisture, and there is no doubt but that a very large part of their success is due to this very large catchment area. . . .

The explanation in support of the dew deposition theory is that the builders of the ponds take careful steps to prevent heat being conducted from the earth to the pond. For this purpose they make a shallow basin in the chalk, then spread a thick layer of straw, or some other non-conductor of heat, and finally the puddling clay on top of this. They ignore the fact that the straw rots and becomes useless as a non-conductor of heat during the first winter. They also like to baptize the pond with snow, and it is generally considered that, if the bottom of the pond is given a nice cool bath to start with, it will keep cool during the hot summer, or a succession thereof!

In 1911 the Royal Society instructed Mr. E. A. Martin, F.G.S., to proceed to the South Downs and investigate these mysterious ponds,

and his findings should once and for all kill the idea that dew is at all responsible for the maintenance of the water.

On investigation, Mr. Martin found that, of the so-called dew ponds which "never run dry in the hottest summer" (according to the testimony of the oldest inhabitant, etc., etc.), nearly all of them failed to hold water in the dry summer of 1911. A few, however, were successful, and were used for watering cattle, so that, taking into consideration the daily evaporation, the loss of water was considerable. In these few ponds the level only slightly fell throughout the summer, showing that water was being received into the ponds. This can only come from three sources (ignoring springs): (1) rain; (2) dew; (3) some hitherto unascertained source. There was no rain (during the summer of 1911), and therefore the cause lay elsewhere.

Now dew, which, of course, is the moisture in the air, is only deposited on something on the earth's surface which is cold—that is to say, below the dew point. On a hot summer's night dew undoubtedly is deposited, as we all know, but, unfortunately, the worst surface to receive dew is that of water, for the simple reason that in water the hottest portion always rises and forms the surface, and on a hot summer's night there is insufficient time for this *hot* surface to fall below the dew point, and no dew can be deposited. This is a scientific fact which is incontestable, and was carefully checked by Mr. Martin in his experiments, wherein he used a large number of recording and other thermometers to ascertain the ground, water and air temperatures during the night.

A second definite fact against the dew theory is that the maximum dewfall recorded anywhere in England is totally insufficient to make up for the water lost by cattle consumption and evaporation. The maximum dewfall is only from 1 to 1½ inches per annum, whilst almost that quantity per night is necessary if the loss during the day is to be made up by dewfall.

Yet a few of these ponds kept going.

It is not until one stays all night by one of these ponds, and that under the right conditions, that the explanation is found, namely that the water comes from the early morning mists or clouds.

As stated, these ponds are always on the hilltops, and close to the sea. I have heard of others inland, but not having examined them I am not convinced that they do not get their supplies from springs in cases where they keep going through a hot summer.

During the chilly early morning hours after a hot summer's night, sea mists roll up over the hills and saturate their tops but not the

valleys, depositing in the hilltop ponds considerably more water than can ever be obtained by dewfall. Furthermore, this deposition and collection is very largely assisted by the surrounding vegetation, and particularly by trees and shrubs which are often arranged on the side of the pond next the coast. The result is that these overhanging shrubs collect moisture from the mists, or clouds, which drops continuously into the pond.

From this it is clear why these self-filling ponds are not to be found in valleys, and it also explains why downland grass near the coast keeps in such a wonderful condition throughout the dryest of summers.

Mr. Martin was able to find a proof that sea mists were responsible for the supply, by testing the ponds for salinity. Sea mist is evaporated sea water, and by mechanical action a slight amount of salt would be expected to be taken up with the moisture. Appropriately, it was found that the ponds nearest the coast had a higher salt content than those more remote.

E. W. Walford in *Discovery*, Vol. V, pp. 245 *f.*

23. The Origin of Novæ (New Stars)

Many attempts have been made to explain the cause of the outburst of a nova and the puzzling changes they undergo, but as yet the riddle has been too much for scientists. To the layman the idea of a collision of two stars would seem most natural. But a closer investigation shows that the stars are separated in space by too great distances to permit collision often enough to supply all the novæ which we are recording on the sky. Besides, a collision of two titanic bodies moving with great speed would produce such an enormous amount of heat that the light of a nova could not fade away as rapidly as our observations show it.

Suggestions were made that a nova originates from a single body supposed to be either a feebly luminous or dark star invisible to us before its outburst. It was surmised that in a certain state of the star's cooling off, the formation of chemical compounds from the simple elements began suddenly in the interior, which process generates considerable energy. And this energy was said to bring the star to an explosion. However, this idea did not become popular, although very recently it has been recalled with certain modifications.

The idea of the passage of a dark star through a local accumulation of cosmical dust or gases has attracted most sympathy and

credulity. Many of these accumulations are observed with the telescope as well as on astronomical photographs. The actual size of these so-called nebulæ is gigantic, and the encounter of a star with nebulosity is considered very plausible. If a dark star traveling in space should enter a nebula at high speed, considerable heat would be generated by the friction, and this would bring aglow the surface of the star, which would appear to us as the outburst of a nova.

Still this hypothesis, proposed by Professor Seeliger years ago, is not in agreement with the evidence supplied by investigation of recent new stars. It appears that the outburst of a new star and the surprising changes it undergoes are not directly produced by changes of its temperature. The temperature of the new stars, as appears from special study, is not any higher than that of ordinary stars. The brilliant Nova Aquilæ (1918) had at maximum light a temperature of 8000 degrees. The new stars in Cygnus (1920) and Pictor (1925) had temperatures of some 7000 and 6000 degrees (the temperature of the sun is about 6000 degrees). The rapid and enormous rise of light of a new star approaching maximum brilliancy is produced rather by the expansion of a dark or feebly luminous star, which increases the luminous surface and results in the increase of its total light. The writer discovered from an investigation of Nova Pictoris of 1925 that two weeks before it reached its maximum brilliancy it was probably about fifty times larger in linear diameter than the sun, but by the time it reached maximum light it ought to have expanded so that it was ninety times as large as the sun.

What the actual cause is that makes certain stars blow off in the spectacular appearance of a nova cannot be definitely said at the present time, but perhaps the most plausible explanation is, as said above, that it passes as a dark star through a nebula. If it is not true that the friction thus generated causes it suddenly to glow, it might be that its sudden light is caused merely by the fact that its passage throws it out of equilibrium, causing its interior gases to lift its upper layers and expanding it so quickly that it seems to burst into our view.

Paul Davidovich in the *Boston Evening Transcript*.

Note that the author molded a new hypothesis out of two of those which were verified negatively. But he admits that this new one has not yet been established.

CHAPTER IX

THE HISTORICAL METHOD

In preceding chapters some of the methods employed in the social sciences have been stressed and a number of examples drawn from this general field of knowledge have been included. There is, however, a method of explanation, widely used in the social sciences, which goes by the name of the *historical method.* It is really a combination of two other methods—the *genetic* and the *comparative* method. Each of these may be used as a separate method. But they may also be employed together and when they are synthesized and fused into a single method they become the historical method.

The genetic method of explanation consists in tracing a complex phenomenon to its origin. The phenomenon under investigation may be an organ or function of a living body, a social institution or custom, a religious ceremony or doctrine, a legal code, a language, a form of literature, a geological deposit or what not. Hence this method can be profitably employed in any science where complex phenomena can be shown to have had a history or to have undergone a temporal development from a lower to a higher form, from a relatively simple to a more complicated structure. To follow such a process of unfolding back to its beginning, to isolate the various *genetic forces*—those forces coöperating to produce the phenomenon under investigation, to understand a later stage by connecting it with an earlier—this is the genetic method of reasoning.

This genetic idea may be said to be the universal methodological assumption of all the social sciences. The basic principle of social organization in any particular social order is known as the *social pattern* of that group. The genetic method, as employed in the social sciences, consists in tracing

human institutions, customs and beliefs back to the social order in which they originated. The social pattern of some particular group is regarded as the essential causative factor in the formation of such customs and doctrines.

The genetic method passes imperceptibly and by logical necessity into the comparative method, which is the explanation of a phenomenon by comparing and contrasting it with other phenomena or by comparing and contrasting one of the stages in its development with another stage. As Ernst Mach [1] has well said: "Comparison, as the fundamental condition of communication, is the most powerful inner vital element of science. The zoölogist sees in the bones of the wing-membranes of bats, fingers; he compares the bones of the cranium with vertebræ, the embryos of different organisms with one another, and the different stages of development of the same organism with one another. The geographer sees in Lake Garda a fjord, in the Sea of Aral a lake in process of drying up. The philologist compares different languages with one another, and the formations of the same language as well. If it is not customary to speak of comparative physics in the same sense that we speak of comparative anatomy, the reason is that in a science of such great experimental activity the attention is turned too much from the *contemplative* element. But like all other sciences, physics lives and grows by comparison."

The historian, the sociologist, the economist, the legal theorizer, the philologist all make use of the genetic and comparative methods in their researches. But they synthesize and fuse them together into a special method of research. This is the historical method. Unique events which may never recur in human experience are thus dealt with scientifically. Their genesis is traced and they are compared and contrasted with events in other cultures or civilizations. All of this elucidates their meaning, brings to light their organic relations, and makes clear their complex ramifications. Hence the historical method is a basic instrument of the social sciences. In importance it must be ranked alongside the statistical

[1] *Popular Scientific Lectures* (Open Court Publishing Co.), p. 239.

method, these two methods having made possible the exceptional growth and extension of the social sciences during the last half century.

The historical method also includes the criticism of texts and documents to determine their authenticity, reliability, date and the circumstances connected with their origin. The *internal evidence* is that which is derived from a detailed analysis of the text or document under investigation. The *external evidence* is that obtained from other sources bearing in any way on the events and ideas dealt with in the original document. This special form of the historical method is basic in such sciences as history and philology.

Although the genetic and the comparative methods are both widely used outside of the social sciences, the examples which follow are all drawn from this general field of knowledge.

WHAT TO READ

In *The God of the Liberal Christian,* Chap. II, I have expounded and evaluated the genetic method, with special reference to its application to religious phenomena. See also the following:

Avey, A. E., *Historical Method in Bible Study,* Chap. II. Especially good on internal and external evidence.
Columbia Associates, *An Introduction to Reflective Thinking,* Chaps. VII, IX, and XI.
Cunningham, H. E., *Textbook of Logic,* Chap. XXIV.
Joseph, H. W. B., *An Introduction to Logic,* pp. 508*f.* and 562*f.*
Langlois and Seignobos, *Introduction to the Study of History.*
Thomas, W. I., *Source Book for Social Origins,* pp. 3-29. Numerous examples of the genetic and comparative methods will be found in this book.

WHAT TO DO WITH THE EXAMPLES

1. Name the complex phenomenon or phenomena which are dealt with in each example, and the science from which each example is drawn.
2. Tell whether the genetic, the comparative or the historical method is most emphasized. Explain your answer, giving at least one reason for it.
3. Do you regard the reasoning as valid? Is the method properly applied? Explain your answer.

1. The Moral As a Growth

The psychologists distinguish *three stages* in conduct: (*a*) Instinctive activity, (*b*) Attention; the stage of conscious direction or control of action by imagery; of deliberation, desire, and choice. (*c*) Habit; the stage of unconscious activity along lines set by previous action. Consciousness thus "occupies a curious middle ground between hereditary reflex and automatic activities upon the one hand and acquired habitual activities upon the other." Where the original equipment of instincts fails to meet some new situation, when there are stimulations for which the system has no ready-made response, consciousness appears. It selects from the various responses those which suit the purpose, and when these responses have become themselves automatic, habitual, consciousness "betakes itself elsewhere to points where habitual accommodatory movements are as yet wanting and needed." (Angell, *Psychology*, p. 59.) To apply this to the moral development we need only to add that this process repeats itself over and over. The starting-point for each later repetition is not the hereditary instinct, but the habits which have been formed. For the habits formed at one age of the individual's life, or at one stage of race development, prove inadequate for more complex situations. The child leaves home, the savage tribe changes to agricultural life, and the old habits no longer meet the need. Attention is again demanded. There is deliberation, struggle, effort. If the result is successful new habits are formed, but upon a higher level. For the new habits, the new character, embody more intelligence. The first stage, purely instinctive action, we do not call moral conduct. It is of course not immoral; it is merely unmoral. The second stage shows morality in the making. It includes the process of transition from impulse, through desire to will. It involves the stress of conflicting interests, the processes of deliberation and valuation, and the final act of choice. It will be illustrated in our treatment of race development by the change from early group life and customs to the more conscious moral life of higher civilization. The third stage, well-organized character, is the goal of the process. But it is evidently only a relative point. A good man has built up a set of habits; a good society has established certain laws and moral codes. But unless the man or society is in a changeless world with no new conditions there will be new problems. And this means that however good the habit was for its time and purpose there must be new choices and new valuations.

A character that would run automatically in every case would be pretty nearly a mechanism. It is therefore the second stage of this process that is the stage of active moral consciousness. It is upon this that we focus our attention.

Moral growth from the first on through the second stage may be described as a process in which man becomes more *rational,* more *social,* and finally more *moral.*

DEWEY and TUFTS, *Ethics* (Henry Holt & Co.), pp. 8 *f.*

2. The Origin of Group Life

Social evolution is rooted in the necessities of organic existence. By biological necessity most species of animals live in groups. The processes of nutrition and reproduction in all the higher forms of life involve a necessary interdependence among organisms of the same species. This necessary interdependence of living forms in the food and reproductive processes has undoubtedly been the basis of social evolution. Animals found it necessary to live in groups in order to procure an adequate food supply, to reproduce and care for offspring, and, lastly, to protect themselves against enemies. These three necessary life-processes from the start gave rise to living in groups. Life, therefore, never developed in an isolated way, each individual by himself. From the very beginning there has been more or less group life among organisms of the same species. The isolated and solitary individual has been an exception in the world of animal life, particularly in all higher forms. Social groups, or groups of organisms carrying on a common life by means of mental interstimulation and response, have their origin in the necessary interdependence of life-processes of organisms of the same species.

Now if this be true, the origin of social or group life is manifestly biological. In its lowliest beginnings such living in groups was merely a phase of organic evolution. At first, too, the interdependence was undoubtedly purely physical, and there can be little doubt that such physical interdependence was the basis upon which later developed the mental interaction which we have seen to be the essence of social life. This mental interdependence must be regarded as a result of the breaking up of the original physical interdependence through the development of relatively independent individuals, who had to retain their unity of activity through interstimulation and response. Social life must be regarded, accordingly, as a higher,

more complex unity of a psychic character which has developed out of a primitive biological unity.

Aside from emphasizing the primitive biological basis of group life, this conclusion is very important for sociological theory because of the serious errors in social theories in the past which come from the assumption that social groups have their origin through the coming together of individuals who were developed in isolation or separateness. In order to obtain society, the theorist had to find a cause which would bring together such individuals developed in isolation. The result was that the organic character of group life was lost sight of, and that the unity of social groups seemed a mystery which could be explained only through some intellectualistic or else some mechanical theory. As soon as we see, however, that group life springs spontaneously from the necessities of the process of living; that it has grown up out of the fundamental phases of that process, namely, the food process, the reproductive process, and defense, then there is no mystery regarding social life. It becomes clear that social life is an expression of the original and continuing interdependence of individuals in a common life-process. But, it may be asked, which factor plays the leading part in the origin and development of social groups—food, reproduction, or defense?

C. A. Ellwood, *The Psychology of Human Society* (D. Appleton & Co.), pp. 50*f*.

Special Question

What are the genetic forces which explain the origin of group life?

3. The Growth of Human Knowledge

Messrs. Dewey, Schiller and their allies, in reaching their general conception of all truth, have only followed the example of geologists, biologists and philologists. In the establishment of these other sciences, the successful stroke was always to take some simple process actually observable in operation—as denudation by weather, say, or variation from parental type, or change of dialect by incorporation of new words and pronunciations—and then to generalize it, making it apply to all times, and produce great results by summating its effects through the ages.

The observable process which Schiller and Dewey particularly

singled out for generalization is the familiar one by which any individual settles into new opinions. The process here is always the same. The individual has a stock of old opinions already, but he meets a new experience that puts them to a strain. Somebody contradicts them; or in a reflective moment he discovers that they contradict each other; or he hears of facts with which they are incompatible; or desires arise in him which they cease to satisfy. The result is an inward trouble to which his mind till then had been a stranger, and from which he seeks to escape by modifying his previous mass of opinions. He saves as much of it as he can, for in this matter of belief we are all extreme conservatives. So he tries to change first this opinion, and then that (for they resist change very variously), until at last some new idea comes up which he can graft upon the ancient stock with a minimum of disturbance of the latter, some idea that mediates between the stock and the new experience and runs them into one another most felicitously and expediently.

This new idea is then adopted as the true one. It preserves the older stock of truths with a minimum of modification, stretching them just enough to make them admit the novelty, but conceiving that in ways as familiar as the case leaves possible. . . .

"Radium" came the other day as part of the day's content, and seemed for a moment to contradict our ideas of the whole order of nature, that order having come to be identified with what is called the conservation of energy. The mere sight of radium paying heat away indefinitely out of its own pocket seemed to violate that conservation. What to think? If the radiations from it were nothing but an escape of unsuspected "potential" energy, pre-existent inside of the atoms, the principle of conservation would be saved. The discovery of "helium" as the radiation's outcome, opened a way to this belief. So Ramsay's view is generally held to be true, because, although it extends our old ideas of energy, it causes a minimum of alteration in their nature. . . .

Now Dewey and Schiller proceed to generalize this observation and to apply it to the most ancient parts of truth. They also once were plastic. They also were called true for human reasons. They also mediated between still earlier truths and what in those days were novel observations. Purely objective truth, truth in whose establishment the function of giving human satisfaction in marrying previous parts of experience with newer parts played no rôle whatever, is nowhere to be found. The reasons why we call things true

is the reason why they *are* true, for "to be true" means only to perform this marriage-function.

WILLIAM JAMES, *Pragmatism* (Longmans, Green & Co.), pp. 58-64.

4. The Origin of the Farmer Capitalist

The serfs, as well as the free small proprietors, held land under very different tenures, and were therefore emancipated under very different economic conditions. In England the first form of the farmer is the bailiff, himself a serf. His position is similar to that of the old Roman *villicus,* only in a more limited sphere of action. During the second half of the 14th century he is replaced by a farmer, whom the landlord provides with seed, cattle, and implements. His condition is not very different from that of the peasant. Only he exploits more wage-labor. Soon he becomes a metayer, a half-farmer. He advances one part of the agricultural stock, the landlord the other. The two divide the total product in proportions determined by contract. This form quickly disappears in England, to give place to the farmer proper, who makes his own capital breed by employing wage-laborers, and pays a part of the surplus-product, in money or in kind, to the landlord as rent. So long, during the 15th century, as the independent peasant and the farm-laborer working for himself as well as for wages, enriched themselves by their own labor, the circumstances of the farmer, and his field of production, were equally mediocre. The agricultural revolution which commenced in the last third of the 15th century, and continued during almost the whole of the 16th (excepting, however, its last decade), enriched him just as speedily as it impoverished the mass of the agricultural people.

The usurpation of the common lands allowed him to augment greatly his stock of cattle, almost without cost, while they yielded him a richer supply of manure for the tillage of the soil. To this was added, in the sixteenth century, a very important element. At that time the contracts for farms ran for a long time, often for ninety-nine years. The progressive fall in the value of the precious metals, and therefore of money, brought the farmers golden fruit. Apart from all the other circumstances discussed above, it lowered wages. A portion of the latter was now added to the profits of the farm. The continuous rise in the price of corn, wool, meat—in a word, of all agricultural produce—swelled the money capital of the farmer without any action on his part, while the rent he paid

(being calculated on the old value of money) diminished in reality. Thus they grew rich at the expense both of their laborers and their landlords. No wonder, therefore, that England, at the end of the sixteenth century, had a class of capitalist farmers, rich, considering the circumstances of the time.

KARL MARX, *Capital* (English translation) p. 474.

Special Questions

1. How many different stages in the evolution of the capitalist farmer does Marx distinguish?
2. To what extent, if any, does he combine the comparative method with the genetic?

5. The Origin of Doctrines of the Atonement

Modern social theologians look upon the various doctrines of the atonement primarily as serving the function of justifying, in terms of the actual changing social practices of dealing with wicked people, God's forgiveness of the sinner. For each social order has a different conception of the preconditions of forgiveness, or to use the same terminology adopted above, each has a different social pattern, the moral aspect of which, so far as the doctrine of the atonement is concerned, is constituted by the preconditions of forgiveness. Hence each successive theory of the atonement is an attempt to interpret God's forgiveness of sinners in terms of the practice of forgiving which rules in the social order out of which it arises.

Thus the *sacrificial theory* of the atonement in the New Testament, according to which Christ is our Passover, grew out of the existing practice of offering a sacrifice to expiate sin, which was the social pattern of the Jewish society in which Christianity arose. Then there developed the *ransom theory* which persisted to the twelfth century. According to one form of this theory Satan had seized some of the elect and held them in torment until God gave Jesus to him as a ransom for their release, whereupon Satan was immediately cheated out of his ransom because the divine power of the Saviour made it impossible for him to be held in the throes of death. Later, under the stress of the new social pattern of feudal society, which in its moral aspect involved the idea that it was wrong to forgive until the injury which had been done to the forgiver's honor had been met, there developed St. Anselm's famous *infinite honor theory*. Jesus' suffering was held to be for the purpose of satis-

fying God's honor, which being infinite required an infinite satisfaction before he could justly forgive sinners. Then with the rise of the absolute monarchies of Europe, in which the moral aspect of the social pattern was the conception of the necessity of punishment of all violators of the king's will, there arose the theory that Jesus' death was to satisfy the *punitive justice* of God. He was morally free to forgive sinners their misdeeds because his punitive justice had fallen on the divine Saviour. *Grotius's theory* of the atonement developed next, created by the social pattern of a predominantly legal society or constitutional monarchy. It held that Jesus suffered to vindicate God as a lawgiver rather than to satisfy his punitive justice. Then there developed the social order known as *bourgeois* society, the pattern of which was property, and the crucifixion was interpreted as the *debt which God paid to satisfy creditors.* Thus the fundamentalists still sing,

> Jesus paid it all,
> All to him I owe.
> Sin had left a crimson stain,
> He washed it white as snow.

For it is natural that the older theories should persist even though new ones are continually being formed.

Thus at least six different social orders may be distinguished, each of which had a distinct social pattern creating a special doctrine of the atonement. And doubtless another theory is now in process of developing, based on the social pattern of our own age.

D. S. Robinson, *The God of the Liberal Christian* (D. Appleton & Co.), pp. 35-37.

Special Questions

1. What is the social pattern for each of the six doctrines?
2. Can each one be regarded as a different stage in the evolution of Christianity?

6. The Growth of the Idea of God

Professor E. S. Ames holds that the proper approach to the God-idea is the tracing of its origin and development. . . . He points out the close relation between the idea of God of a certain people and their general social organization. Thus a nomadic or a hunting social group believes in and worships animal gods, a tribe of fishermen develops fish gods, and an agricultural folk create rain and

grain gods. When the life of a group becomes so complicated and diversified as to include a number of separate activities, that people is certain to develop syncretized deities, that is to say, gods which combine in themselves several specific functions previously attributed to separate deities. And when social organization advances still further to the point where great human leaders, such as sheiks, patriarchs, kings, warriors, and what not, control the destinies of the people, the gods forthwith take on the characteristics of these potentates. Moreover, that God and the social consciousness are one and the same is further borne out by the fact, well known to the historian of religion, that when a race is conquered its gods become the vassals of the gods of the conquerors. Then, too, when a homogeneous group is dispersed by a more powerful rival, so that its tribal identity is lost, its god becomes a jinn, a mere ghost of its former self, or else disappears entirely and becomes a dead god.

Nor is this deifying or rather God-creating process a mere past phenomenon which is no longer active. Every social psychologist is familiar with the psychological process in present-day life which is all the time personifying lesser social groups, such as the spirit of a college as *Alma Mater,* or the national consciousness as *Uncle Sam,* even though these personifications are not, as among primitive men, conceived of as minor deities. But we do still personify the whole social order as the one supreme God, "the Common Will idealized and magnified and presented in personal symbolism," to quote a significant characterization from Professor Ames.

Idem, pp. 125*f.*

7. The Evolution of Punitive Law

Let us . . . examine the beginnings of punitive law. After all, even under the sway of custom, casual outbreaks are liable to occur. Some one's passions will prove too much for him, and there will be an accident. What happens then in the primitive society? Let us first consider one of the very unorganized communities at the bottom of the evolutionary scale; as, for example, the little Negritos of the Andaman Islands. Their justice, explains Mr. Man, in his excellent account of these people, is administered by the simple method of allowing the aggrieved party to take the law into his own hands. This he usually does by flinging a burning faggot at the offender, or by discharging an arrow at him, though more frequently near him. Meanwhile all others who may be present are apt to beat a speedy retreat, carrying off as much of their property

as their haste will allow, and remaining hid in the jungle until sufficient time has elapsed for the quarrel to have blown over. Sometimes, however, friends interpose, and seek to deprive the disputants of their weapons. . .

Now here we seem to find want of social structure and want of law going together as cause and effect. The "friends" of whom we hear need to be organized into a police force. If we now turn to totemic society, with its elaborate clan-system, it is quite another story. Blood-revenge ranks amongst the foremost of the clansman's social obligations. Over the whole world it stands out by itself as the type of all that law means for the savage. . . . Between clans of the same tribe, the system of blood-revenge requires strict reprisals, according to the principle that some one on the other side, though not necessarily the actual murderer, must die the death. This is known as the principle of collective responsibility; and one of the most interesting problems relating to the evolution of early law is to work out how individual responsibility gradually develops out of collective, until at length, even as each man does, so likewise he suffers.

The collective method of settling one's grievances is natural enough, when men are united into groups bound together by the closest of sentimental ties and on the other hand there is no central and impartial authority to arbitrate between the parties. One of our crew has been killed by one of your crew. So a stand-up fight takes place. Of course we should like to get at the right man if we could; but, failing that, we are out to kill some one in return, just to teach your crew a lesson. Comparatively early in the day, however, it strikes the savage mind that there are degrees of responsibility. For instance, some one has to call the avenging party together, and to lead it. He will tend to be a real blood-relation, son, father, or brother. Thus he stands out as champion, whilst the rest are in the position of mere seconds. Correspondingly, the other side will tend to thrust forward the actual offender into the office of counter-champion. There is direct evidence to show that, amongst Australians, Eskimos, and so on, whole groups at one time met in battle, but later on were represented by chosen individuals, in the persons of those who were principals in the affairs. Thus we arrive at the duel. The transition is seen in such a custom as that of the Port Lincoln black-fellows. The brother of the murdered man must engage the murderer; but any one on either side who might care to join in the fray was at liberty to do so. Hence it is but a step to

the formal duel, as found, for instance, amongst the Apaches of North America.

Now the legal duel is an advance on the collective bear-fight, if only because it brings home to the individual perpetrator of the crime that he will have to answer for it. Cranz, the great authority on the Eskimo of Greenland, naïvely remarks that a Greenlander dare not murder or otherwise wrong another, since it might possibly cost him the life of his best friend. Did the Greenlander know that it would probably cost him his own life, his sense of responsibility, we may surmise, might be somewhat quickened. On the other hand, duelling is not a satisfactory way of redressing the balance, since it merely gives the powerful bully an opportunity of adding a second murder to the first. Hence the ordeal marks an advance in legal evolution. A good many Australian peoples, for example, have reached the stage of requiring the murderer to submit to a shower of spears or boomerangs at the hands of the aggrieved group, on the mutual understanding that the blood-revenge ends here.

Luckily, however, for the murderer, it often takes time to bring him to book; and angry passions are apt in the meanwhile to subside. The ruder savages are not so bloodthirsty as we are apt to imagine. War has evolved like everything else; and with it has evolved the man who likes fighting for its own sake. So, in place of a life for a life, compensation—"pacation," as it is technically termed—comes to be recognized as a reasonable *quid pro quo*. Constantly we find custom at the half-way stage. If the murderer is caught soon, he is killed; but if he can stave off the day of justice, he escapes with a fine. When private property has developed, the system of blood-fines becomes most elaborate. Amongst the Iroquois the manslayer must redeem himself from death by means of no less than sixty presents to the injured kin; one to draw the axe out of the wound, a second to wipe the blood away, a third to restore peace to the land, and so forth. According to the collective principle, the clansmen on one side share the price of atonement, and on the other side must tax themselves in order to make it up. Shares are on a scale proportionate to degrees of relationship. Or, again, further nice calculations are required, if it is sought to adjust the gross amount of the payment to the degree of guilt. Hence it is not surprising that, when a more or less barbarous people, such as the Anglo-Saxons, came to require a written law, it should be almost entirely taken up by regulations about blood-fines, that had become too complicated for the people any longer to keep in their heads.

So far we have been considering the law of blood-revenge as purely an affair between the clans concerned; the rest of the tribal public keeping aloof very much in the style of the Andamanese bystanders who retire into the jungle when there is a prospect of a row. But with the development of a central authority, whether in the shape of the rule of many or of one, the public control of the blood-feud begins to assert itself; for the good reason that endless vendetta is a dissolving force, which the larger and more stable type of society cannot afford to tolerate if it is to survive. The following are a few instances illustrative of the transition from private to public jurisdiction. In North America, Africa, and elsewhere, we find the chief or chiefs pronouncing sentence, but the clan or family left to carry it out as best they can. Again the kin may be entrusted with the function of punishment, but obliged to carry it out in the way prescribed by the authorities; as, for instance, in Abyssinia, where the nearest relation executes the manslayer in the presence of the king, using exactly the same kind of weapon as that with which the murder was committed. Or the right of the kin to punish dwindles to a mere form. Thus in Afghanistan the elders make a show of handing over the criminal to his accusers, who must, however, comply strictly with the wishes of the assembly; whilst in Samoa the offender was bound and deposited before the family "as if to signify that he lay at their mercy," and the chief saw to the rest. Finally, the state, in the person of its executive officers, both convicts and executes.

When the state is represented by a single ruler, crime tends to become an offence against "the king's peace"—or, in the language of Roman law, against his "majesty." Henceforward, the easy-going system of getting off with a fine is at an end, and murder is punished with the utmost sternness. In such a state as Dahomey, in the old days of its independence, there may have been a good deal of barbarity displayed in the administration of justice, but at any rate human life was no less effectively protected by the law than it was, say, in mediæval Europe.

R. R. Marett, *Anthropology* (Henry Holt & Co.), pp. 188-194.

Special Questions

1. How many different stages in the evolution of punishment does the author distinguish?
2. List the different tribes compared in the example.

8. The Growth of Indian Mythologies

As we depart from the area where the peculiar culture of the North Pacific coast has reached its highest development, a gradual change in arts and customs takes place, and, together with it, we find a gradual diminution in the number of myths which the distant tribe has in common with the people of the North Pacific coast. At the same time, a gradual change in the incidents and general character of the legends takes place.

We can in this manner trace what we might call a dwindling down of an elaborate cyclus of myths to mere adventures, or even to incidents of adventures, and we can follow the process step by step. Wherever this distribution can be traced, we have a clear and undoubted example of the gradual dissemination of a myth over neighboring tribes. The phenomena of distribution can be explained only by the theory that the tales have been carried from one tribe to its neighbors, and by the tribe which has newly acquired them in turn to its own neighbors. It is not necessary that this dissemination should always follow one direction; it may have proceeded either way. In this manner a complex tale may dwindle down by gradual dissemination, but also new elements may be embodied in it.

It may be well to give an example of this phenomenon. The most popular tradition of the North Pacific coast is that of the raven. Its most characteristic form is found among the Tlingit, Tsimshian, and Haida. As we go southward, the connection between the adventures becomes looser and their number less. It appears that the traditions are preserved quite fully as far south as the north end of Vancouver Island. Farther south the number of tales which are known to the Indians diminishes very much. At Newettee, near the north point of Vancouver Island, thirteen tales out of a whole of eighteen exist. The Comox have only eight, the Nootka six, and the Coast Salish only three. Furthermore, the traditions are found at Newettee in the same connection as farther north, while farther south they are very much modified. The tale of the origin of daylight, which was liberated by the raven, may serve as an instance. He had taken the shape of a spike of a cedar, was swallowed by the daughter of the owner of the daylight, and then born again; afterwards he broke the box in which the daylight was kept. Among the Nootka, only the transformation into the spike of a cedar, which is swallowed by a girl and then born again, remains. Among the Coast Salish the more important passages survive, telling

how the raven by a ruse compelled the owner of the daylight to let it out of the box in which he kept it. The same story is found as far south as Grey's Harbor in Washington. The adventure of the pitch, which the raven kills by exposing it to the sunshine, intending to use it for caulking his canoe, is found far south, but in an entirely new connection, embodied in the tradition of the origin of sun and moon.

F. Boas, *Journal of American Folklore,* Vol. IX, pp. 1*f.*

After giving the above account of the dissemination of the mythologies of the Indians of the North Pacific Coast the author goes on to distinguish his way of using the comparative method from that of others.

9. Two Ways of Using the Comparative Method

It may be well to dwell on the difference between that comparative method which I have pursued in my inquiry and that applied by many investigators of ethnographical phenomena. I have strictly confined my comparisons to contiguous areas in which we know intercourse to have taken place. I have shown that this area extends from the Pacific coast to considerable distances. It is true that the mythologies of the far east and the extreme northeast are not as well connected with those of the Pacific coast by intermediate links as they might be, and I consider it essential that a fuller amount of material from intermediate points be collected in order that the investigation which I have begun may be carried out in detail. But a comparison of the fragmentary notes which we possess from intermediate points proves that most of those tales which I have enumerated as common to the east, to the north, and to the west, will be found covering the whole area continuously. Starting from this fact, we may be allowed to argue that those complex tales which are now found only in isolated portions of our continent either are actually continuous but have not been recorded from intermediate points; or that they have become extinct in intermediate territory; or, finally, that they were carried over certain areas accidentally, without touching the intermediate field. This last phenomenon may happen, although probably not to a very great extent. I observed one example of this kind on the Pacific coast, where a tale which has its home in Alaska is found only in one small group of tribes on southern Vancouver Island, where, as can be proved, it has been carried either by visitors or by slaves.

The fundamental condition, that all comparisons must be based on material collected in contiguous areas, differentiates our method from that of investigators like Petitot and many others, who see a proof of dissemination or even of blood relationship in each similarity that is found between a certain tribe and any other tribe of the globe. It is clear that the greater the number of tribes which are brought forward for the purposes of such comparisons the greater also the chance of finding similarities. It is impossible to derive from such comparisons sound conclusions, however extensive the knowledge of literature that the investigator may possess, for the very reason that the complex phenomenon found in one particular region is compared to fragmentary evidence from all over the world. By means of such comparisons, we can expect to find resemblances which are founded in the laws of the development of the human mind, but they can never be proofs of transmission of customs or ideas.

Idem, pp. 7*f*.

Special Questions

1. Which do you regard as the more scientific way of using the comparative method—that of Boas or that of Petitot? Explain your answer.
2. Which way of using the comparative method did Marett use in example number 7?

10. The Evolution of Conduct

Complete comprehension of conduct is not to be obtained by contemplating the conduct of human beings only: we have to regard this as a part of universal conduct—conduct as exhibited by all living creatures. For evidently this comes within our definition—acts adjusted to ends. The conduct of the higher animals as compared with that of man, and the conduct of the lower animals as compared with that of the higher, mainly differ in this, that the adjustments of acts to ends are relatively simple and relatively incomplete. And as in other cases, so in this case, we must interpret the more developed by the less developed. Just as, fully to understand the part of conduct which Ethics deals with, we must study human conduct as a whole; so, fully to understand human conduct as a whole, we must study it as a part of that larger whole constituted by the conduct of animate beings in general. . . . Conduct is distinguished from the totality of actions by excluding purposeless actions; but during evolution this distinction arises by degrees. In

the very lowest creatures most of the movements from moment to moment made, have not more recognizable aims than have the struggles of an epileptic. An infusorium swims randomly about, determined in its course not by a perceived object to be pursued or escaped, but, apparently, by varying stimuli in its medium; and its acts, unadjusted in any appreciable way to ends, lead it now into contact with some nutritive substance which it absorbs, and now into the neighbourhood of some creature by which it is swallowed and digested. Lacking those developed senses and motor powers which higher animals possess, ninety-nine in the hundred of these minute animals, severally living but for a few hours, disappear either by innutrition or by destruction. The conduct is constituted of actions so little adjusted to ends, that life continues only as long as the accidents of the environment are favourable. But when, among aquatic creatures, we observe one which, though still low in type, is much higher than the infusorium—say a rotifer—we see how, along with larger size, more developed structures, and greater power of combining functions, there goes an advance in conduct. We see how by its whirling cilia it sucks in as food these small animals moving around; how by its prehensile tail it fixes itself to some object; how by withdrawing its outer organs and contracting its body, it preserves itself from this or that injury from time to time threatened; and how thus, by better adjusting its own actions, it becomes less dependent on the actions going on around, and so preserves itself for a longer period.

A superior sub-kingdom, as the Mollusca, still better exemplifies this contrast. When we compare a low mollusc, such as a floating ascidian, with a high mollusc, such as a cephalopod, we are again shown that greater organic evolution is accompanied by more evolved conduct. At the mercy of every marine creature large enough to swallow it, and drifted about by currents which may chance to keep it at sea or may chance to leave it fatally stranded, the ascidian displays but little adjustment of acts to ends in comparison with the cephalopod; which, now crawling over the beach, now exploring the rocky crevices, now swimming through the open water, now darting after a fish, now hiding itself from some larger animal in a cloud of ink, and using its suckered arms at one time for anchoring itself and at another for holding fast its prey; selects, and combines and proportions its movements from minute to minute, so as to evade dangers which threaten, while utilizing chances of food which offer; so showing us varied activities which

in achieving special ends, achieve the general end of securing continuance of the activities.

Among vertebrate animals we similarly trace up, along with advance in structures and functions, this advance in conduct. A fish roaming about at hazard in search of something to eat, able to detect it by smell or sight only within short distances, and now and again rushing away in alarm on the approach of a bigger fish, makes adjustments of acts to ends that are relatively few and simple in their kinds; and shows us, as a consequence, how small is the average duration of life. So few survive to maturity that, to make up for destruction of unhatched young and small fry and half-grown individuals, a million ova have to be spawned by a cod-fish that two may reach the spawning age. Conversely, by a highly-evolved mammal, such as an elephant, those general actions performed in common with the fish are far better adjusted to their ends. By sight as well, probably, as by odour, it detects food at relatively great distances; and when, at intervals, there arises a need for escape, relatively great speed is attained. But the chief difference arises from the addition of new sets of adjustments. We have combined actions which facilitate nutrition—the breaking off of succulent and fruit-bearing branches, the selecting of edible growths throughout a comparatively wide reach; and, in case of danger, safety can be achieved not by flight only, but, if necessary by defence or attack: bringing into combined use tusks, trunk, and ponderous feet. Further, we see various subsidiary acts adjusted to subsidiary ends—now the going into a river for coolness, and using the trunk as a means of projecting water over the body; now the employment of a bough for sweeping away flies from the back; now the making of signal sounds to alarm the herd, and adapting the actions to such sounds when made by others. Evidently, the effect of this more highly-evolved conduct is to secure the balance of the organic actions throughout far longer periods.

And now, on studying the doings of the highest of mammals, mankind, we not only find that the adjustments of acts to ends are both more numerous and better than among lower mammals; but we find the same thing on comparing the doings of higher races of men with those of lower races. If we take any one of the major ends achieved, we see greater completeness of achievement by civilized than by savage; and we also see an achievement of relatively numerous minor ends subserving major ends. Is it in nutrition? The food is obtained more regularly in response to appetite; it is

far higher in quality; it is free from dirt; it is greater in variety; it is better prepared. Is it in warmth? The characters of the fabrics and forms of the articles used for clothing, and the adaptations of them to requirements from day to day and hour to hour, are much superior. Is it in dwellings? Between the shelter of boughs and grass which the lowest savage builds, and the mansion of the civilized man, the contrast in aspect is not more extreme than is the contrast in number and efficiency of the adjustments of acts to ends betrayed in their respective constructions. And when with the ordinary activities of the savage we compare the ordinary civilized activities—as the business of the trader, which involves multiplied and complex transactions extending over long periods, or as professional avocations, prepared for by elaborate studies and daily carried on in endlessly varied forms, or as political discussions and agitations, directed now to the carrying of this measure and now to the defeating of that,—we see sets of adjustments of acts to ends, not only immensely exceeding those seen among lower races of men in variety and intricacy, but sets to which lower races of men present nothing analogous. And along with this greater elaboration of life produced by the pursuit of more numerous ends, there goes that increased duration of life which constitutes the supreme end.

HERBERT SPENCER, *Principles of Ethics* (D. Appleton & Co.), pp. 6-14.

Special Questions

1. List the various stages in the evolution of conduct.
2. Does the author prove or does he simply assume that there is an organic connection between these stages?

11. The Abuse of the Comparative Method

The psychical attitudes and traits of the savage are more than stages through which mind has passed, leaving them behind. They are outgrowths which have entered decisively into further evolution, and as such form an integral part of the framework of present mental organization. Such positive significance is commonly attributed, in theory at least, to animal mind; but the mental structure of the savage, which presumably has an even greater relevancy for genetic psychology, is strangely neglected.

The cause of this neglect I believe lies in the scant results so far secured, because of the abuse of the comparative method—which abuse in turn is due to the lack of a proper method of interpretation.

Comparison as currently employed is defective—even perverse—in at least three respects. In the first place, it is used indiscriminately and arbitrarily. Facts are torn loose from their context in social and natural environment and heaped miscellaneously together because they have impressed the observer as alike in some respect. Upon a single page of Spencer, which I chanced to open in looking for an illustration of this point, appear Kamschadales, Kirghiz, Bedouins, East Africans, Bechuanas, Damaras, Hottentots, Malays, Papuans, Fijians, Andamanese—all cited in reference to establish a certain common property of primitive minds. What would we think of a biologist who appealed successively to some external characteristic of say snake, butterfly, elephant, oyster and robin in support of a statement? And yet the peoples mentioned present widely remote cultural resources, varied environments and distinctive institutions. What is the scientific value of a proposition thus arrived at?

In the second place, this haphazard, uncontrollable selection yields only static facts—facts which lack the dynamic quality necessary to a genetic consideration. The following is a summary of Mr. Spencer's characterizations of primitive man, emotional and intellectual:

He is explosive and chaotic in feeling, improvident, childishly mirthful, intolerant of restraint, with but small flow of altruistic feeling, attentive to meaningless detail and incapable of selecting the facts from which conclusions may be drawn, with feeble grasp of thought, incapable of rational surprise, incurious, lacking in ingenuity and constructive imagination. Even the one quality which is stated positively, namely, keenness of perception, is interpreted in a purely negative way, as a character antagonistic to reflective development. "In proportion as the mental energies go out in restless perception, they cannot go out in deliberate thought." And this from a sensationalist in psychology!

Such descriptions as these also bear out my first point. Mr. Spencer himself admits frequent and marked discrepancies (e.g., pp. 56, 59, 62, 65, etc., *Sociology*, Vol. I), and it would not be difficult to bring together a considerable mass of proof-texts to support the exact opposite of each of his assertions. But my point here is that present civilized mind is virtually taken as a standard, and savage mind is measured off on this fixed scale.

It is no wonder that the outcome is negative; that primitive mind is described in terms of "lack," "absence": its traits are incapacities.

Qualities defined in such fashion are surely useless in suggesting, to say nothing of determining, progress, and are correspondingly infertile for genetic psychology, which is interested in becoming, growth, development.

The third remark is that the results thus reached, even passing them as correct, yield only loose aggregates of unrelated traits—not a coherent scheme of mind. We do not escape from an inorganic conglomerate conception of mind by just abusing the "faculty" psychology. Our standpoint must be more positive. We must recognize that mind has a pattern, a scheme of arrangement in its constituent elements, and that it is the business of a serious comparative psychology to exhibit these patterns, forms or types in detail. By such terms, I do not mean anything metaphysical; I mean to indicate the necessity of a conception such as is a commonplace with the zoölogist. Terms like articulate or vertebrate, carnivore or herbivore, are "pattern" terms of the sort intended. They imply that an animal is something more than a random composite of isolated parts, made by taking an eye here, an ear there, a set of teeth somewhere else. They signify that the constituent elements are arranged in a certain way; that in being co-adapted to the dominant functions of the organism they are of necessity co-related with one another. Genetic psychology of mind will advance only as it discovers and specifies generic forms or patterns of this sort in psychic morphology.

JOHN DEWEY in *The Psychological Review*, Vol. IX, pp. 217*f*.

Special Questions

1. Is Dewey's criticism of Spencer's use of the comparative method valid against Boas' use of it as explained in example number 9?
2. Is Dewey's criticism of Spencer identical with Boas' criticism of Petitot and others?
3. What method do you think Dewey has in mind as a substitute for the method of Spencer? (Note especially the last two paragraphs of the example.) Do you think he meant that the comparative method should be modified as Boas modified it or in some other way? If the latter, which way?

12. The Family Theory of the Origin of the State

The most widely accepted theory of the state and of the nation, in so far as state and nation are confused, is that the nation is an enlargement of the family, and the state a development of the

paternal authority. We find this theory so far as it affects the state definitely formulated by Plato in his *Laws* and it has been repeated in different forms by most writers on the development of society from his time on. If this theory be accepted it would explain why both racial descent and language have been adopted as the criteria of nationality. Were the human organization to have developed from the family, all members of the nation would speak a common tongue and all would be blood relations, which would be descendants of common ancestors. One could expect to trace the members of the nation by the physical similarities as well as by the similarities in speech. The nation would be a real biological unit. On the mental side, one might think of the nation as united by an extension of the family ties. The solidarity would be an extension of the family solidarity and the social instincts would be the racial instincts in a wider application.

In all primitive communities there is some evidence for identity between the family and the narrower political units. Kindred and clan are recognized among all of the races of Northern Europe until well down into mediæval times, and traces can be found in remote districts until within two centuries. The system of land holding in early England shows many traces of the original family connections, and still more strikingly, the system of money payments to kindred for slaying a member is conclusive evidence of the solidarity of the kindred in all the Teutonic peoples. Here we seem to approach the condition demanded by the theory that the children of one father form a single group and these are united for purposes of receiving and paying the *weregild* or blood money into larger groups or kindred to the fourth and sometimes to the eighth or ninth degree of relationship. The kindred or clan was an administrative unit as well as a group bound by ties of friendliness, a social unit. From the clan various groupings are made in different lands, but in all alike the larger groups found are aggregations of clans. Whether the lines of descent are recognized in the larger groups is not so clear. Certainly there is evidence that new groupings of clans that do not recognize degrees of blood relationship may be made in an emergency, and that in ordinary circumstances the degree of blood relationship, if the unit extends beyond the clan, has little to do with the system of organization.

W. B. Pillsbury, *The Psychology of Nationality and Internationalism* (D. Appleton & Co.), pp. 6*f*.

Special Questions

1. What evidence is there in the last paragraph that the author does not accept the theory he has expounded?
2. To what extent does the theory seem to be true?

13. Stages in the Growth of the Idea of Progress

In the sixties of the nineteenth century the idea of Progress entered upon the third period of its history. During the *first* period, up to the French Revolution, it had been treated rather casually; it was taken for granted and received no searching examination either from philosophers or from historians. In the *second* period its immense significance was apprehended and a search began for a general law which would define and establish it. The study of sociology was founded, and at the same time the impressive results of science, applied to the conveniences of life, advertised the idea. It harmonised with the notion of "development" which had become current both in natural science and in metaphysics. Socialists and other political reformers appealed to it as a gospel.

By 1850 it was a familiar idea in Europe, but was not yet universally accepted as obviously true. The notion of social Progress had been growing in the atmosphere of the notion of biological development, but this development still seemed a highly precarious speculation. The fixity of species and the creation of man, defended by powerful interests and prejudices, were attacked but were not shaken. The hypothesis of organic evolution was much in the same position as the Copernican hypothesis in the sixteenth century. Then in 1859 Darwin intervened, like Galileo. The appearance of the *Origin of Species* changed the situation by disproving definitely the dogma of fixity of species and assigning real causes for "transformism." What might be set aside before as a brilliant guess was elevated to the rank of a scientific hypothesis, and the following twenty years were enlivened by the struggle around the evolution of life, against prejudices chiefly theological, resulting in the victory of the theory.

The *Origin of Species* led to the *third* stage of the fortunes of the idea of Progress. We saw how the heliocentric astronomy, by dethroning man from his privileged position in the universe of space and throwing him back on his own efforts, had helped that idea to compete with the idea of a busy Providence. He now suffers a new degradation within the compass of his own planet. Evolution, shear-

ing him of his glory as a rational being specially created to be the lord of the earth, traces a humble pedigree for him. And this second degradation was the decisive fact which has established the reign of the idea of Progress.

J. B. Bury, *The Idea of Progress* (The Macmillan Co.), pp. 334*f*.

Special Question

What genetic force brought the idea of progress to the third stage?

14. Mother-Right *versus* Father-Right

In the early stages of historical investigation into the beginnings of civilization it was thought that society arose out of the patriarchal family and that in Abraham, Isaac and Jacob, or again in the Roman *pater familias*, as we reconstruct him from the laws of the Twelve Tables and what we know of earlier Roman law, we have a type of primitive human government. The researches of Bachofen, McLennan, Morgan, and others opened up an entirely new field of speculation. It was shown that the lower we go in the scale of civilization the more prevalent we find a type of organization which is in many ways the opposite of patriarchal, putting the mother for many purposes into the father's position. Amongst civilized nations which have passed out of this stage we find indubitable traces of their having gone through it at an earlier period. These observations led to the setting up a matriarchal, as opposed to the patriarchal, theory, and to the belief that in the dim red dawn of man there was a golden age of woman, which later on passed into the iron age of male despotism. The facts were sound, but the inference drawn from them was precarious, for it was not sufficiently recognized that there was a distinction between *matriarchy*, the rule of the mother, and what I have spoken of already as *mother-right*, rule going through the mother and dependent on the mother. What is really common among the lower savages, and may even have been universal at a certain stage, is not matriarchy, but mother-right, and along with mother-right, and where it most flourishes, it is perfectly possible for the position of women to be as low as the greatest misogynist could desire. The actual number of cases in which the woman has a controlling or even an equal position are very few. I will mention one or two of them later on. As a general rule, where the father is not head of the household that place is taken by the wife's brother, and the maternally organized clan consists of

units composed each of a woman, her brothers, and her children. The woman is not necessarily any better off because she is ruled by a brother in place of a husband.

Let us set the two types of family in contrast. Under mother-right the wife, under father-right the husband, is the pivot on which the family relationships turn. Under mother-right the wife remains a member of her own family. Under father-right she passes out of her family altogether, she is even separated from the family cult and family gods, her husband's people are her people and his gods her gods. Under mother-right the children take the mother's name and belong to her kindred. In cases of divorce they follow the mother. It is the mother's family who protects them. Her brother is their natural guardian, and exercises all the rights and duties which may belong to that position. The maternal kinsfolk stand together in the blood feud, they and not the husband protect or avenge the wife and her children. They may even protect her and them from the husband himself. In extreme cases the children are not held to be related to their father or to their father's family at all, whence in some peoples, half-brother and half-sister may intermarry as in the well-known case of Abraham and Sarah. Under father-right, on the contrary, it is relationship through the male which counts. The father is the natural guardian and protector of the children and in case of divorce retains them. It is to him and his kin that wife and children look for protection. In extreme cases it is only such relationship that is regarded. The wife and her children cease to have claims on her family, while relationship to the male ancestors and descendants is traced to the remotest degrees. These consequences of the strict principle of father-right, however, are seldom pushed to the full length. Relationship through the mother is generally a bar to marriage, though the degrees are not carried so far as upon the masculine side; nor is the wife often so cut off from her relations as the strict consequences of the paternal theory might lead us to expect. Her family as a rule retains a right of protecting her if she is ill-treated; she will fly to them for succour, and their right to guard her is recognized. Lastly, under mother-right the property passes through the woman, if not to the woman. Under father-right it goes from father to son.

L. T. Hobhouse, *Morals in Evolution*, Vol. I (Henry Holt & Co.), pp. 160 *f.*

15. The Evolution of the Law of Property

In general the historical development of the law of property follows the line thus indicated by analysis. In the most primitive social control only natural possession is recognized and interference with natural possession is not distinguished from interference with the person or injury to the honor of the one whose physical contact with the physical object is meddled with. In the earlier legal social control the all-important thing is seisin, or possession. This is a juristic possession, a conception both of fact and of law. Such institutions as tortious conveyance by the person seised in the common law are numerous in an early stage of legal development. They show that primarily the law protected the relation to an object of one who had possession of it. Indeed the idea of *dominium*, or ownership as we now understand it, was first worked out thoroughly in Roman law, and other systems got their idea of it, as distinguished from seisin, from the Roman books.

Recognition of individual interests of substance, or in other words individual property, has developed out of recognition of group interest, just as recognition of individual interests of personality has evolved gradually from what in the first instance was a recognition of group interest. The statement which used to be found in the books that all property originally was owned in common means nothing more than this. When interests of substance are first secured they are interests of groups of kindred because in tribally organized society groups of kindred are the legal units. Social control secures these groups in the occupation of things which they have reduced to their possession. In this sense the first property is group rather than individual property. Yet it must be noted that wherever we find a securing of group interest, the group in occupation is secured against interference of other groups with that occupation. Two ideas gradually operated to break up these group interests and bring about recognition of individual interests. One of these is the partition of households. The other is the idea of what in the Hindu law is called self-acquired property.

In primitive or archaic society as households grow unwieldy there is a partition which involves partition of property as well as of the household. Indeed in Hindu law partition is thought of as partition of the household primarily and as partition of property only incidentally. Also in Roman law the old action for partition is called the action for partitioning the household. Thus, at first, partition

is a splitting up of an overgrown household into smaller households. Presently, however, it tends to become a division of a household among individuals. Thus in Roman law on the death of the head of a household each of his sons in his power at his death became a *pater familias* and could bring a proceeding to partition the inheritance although he might be the sole member of the household of which he was the head. In this way individual ownership became the normal condition instead of household ownership. In Hindu law household ownership is still regarded as the normal condition. But with changes in society and the rise of commercial and industrial activity, a change has been taking place rapidly which is making individual ownership the normal type in fact, if not in legal theory.

Self-acquired property, the second disintegrating agency, may be seen in Hindu law and also in Roman law. In Hindu law all property is normally and *prima facie* household property. The burden is upon anyone who claims to be the individual owner of anything. But an exceptional class of property is recognized which is called self-acquired property. Such property might be acquired by "valor," that is, by leaving the household and going into military service and thus earning or acquiring by way of booty, or by "learning," that is, by withdrawing from the household and devoting oneself to study and thus acquiring through the gifts of the pious or the exercise of knowledge. A third form was recognized later, namely, property acquired through the use of self-acquired property. In the same way in Roman law the son in the household, even if of full age, normally had no property. Legally all property acquired by any member of the household was the property of the head of the household as the legal symbol and representative thereof. Later the head of the household ceases to be thought of as symbolizing the household and the property was regarded legally as his individual property. But Roman law recognized certain kinds of property which sons in the household might hold as their own. The first of these was property earned or acquired by the son in military service. Later property earned in the service of the state was added. Finally it came to be law that property acquired otherwise than through use of the patrimony of the household might be held by the son individually though he remained legally under the power of the head.

In the two ways just explained, through partition and through the idea of self-acquired property, individual interests in property came to be recognized throughout the law. Except for the institution of

community property between husband and wife in civil-law countries, or as it is called the matrimonial property régime, there is practically nothing left of the old system of recognized group interests. And even this remnant of household group ownership is dissolving.

ROSCOE POUND, *An Introduction to the Philosophy of Law* (Yale University Press), pp. 224-229.

16. The Concept of Development in Psychology

When we set out to make a psychological study of the world in which we live, we continually come upon facts that can be understood only after we conceive them as products of evolution. For a long time psychological theory was dominated by the question: How much of any observed fact can be explained as a process of development? And even today no agreement has been reached between the rival theories of *empiricism* and *nativism*, the first of which emphasizes the influence of environment, and the second the influence of heredity. With this situation before us it is surprising to learn—though historically not difficult to understand—that psychology—and German psychology in particular—has made so little use of the general principles of development. Indeed, from the point of view of experience, the problem of development has been dealt with in a very specialized way, which is mechanistic rather than truly biological. This period seems, however, to be drawing to a close; for the need is now felt of introducing the facts of psychology into a larger sphere, embracing other facts of life, from which our science has already departed too far. We must therefore try to envisage the problems of mental growth as they really are; we must seek to understand the peculiarities of mental evolution, and must endeavour to discover its laws.

In the accomplishment of this task we should not forget that the subject of a psychological investigation is usually the mature and cultured "West European" type of man; a living being—biologically considered—at the highest level of development. In the first place, we are dealing with the human being as opposed to the animal. Since Darwin's time, the conception of the descent of man has become common property, and we assume that what is valid in morphology and physiology must also have its significance in psychology. In the second place, we are dealing with representatives of a highly differentiated, as opposed to the members of a primitive civilization. The world appears otherwise to us than it does to a negro in Central

Africa and otherwise than it did to Homer. We speak a different language from each of these, and this difference is a fundamental one, inasmuch as a real translation of their words into our own is impossible, because the categories of thought are different. In the third place we are dealing with the adult as opposed to the child, though each of us was once a child, and has become an adult only by having outgrown his childhood.

We must not forget, then, that without a comparative psychology, without animal-, folk-, and child-psychology, the experimental psychology of the human adult is and must remain defective. For this reason the psychology of the human adult has not infrequently and in various respects been unable to define its problems correctly, to say nothing of arriving at serviceable hypotheses. For instance, the error has often been committed of trying to explain a fact by merely referring to its evolution, thus building up a theory of evolution instead of first investigating the facts by comparative methods. Whenever one has had a genetic problem to deal with, the danger has always been great that one would accept the old hypotheses and apply them to his new facts, instead of first giving his facts an unprejudiced consideration.

KURT KOFFKA, *The Growth of the Mind* (Harcourt, Brace & Co.).

Special Questions

1. What is Koffka's criticism of the genetic method as used in psychology?
2. With what should the evolution of adult experience be compared?

17. Legal Problems in Typewriting

Three main questions arise regarding typewriting. First, as to whether a particular document was written on a certain individual machine. Second, whether a document was written all on one machine and written continuously, or whether it was written at two different times on the same machine after the paper had been taken from the machine, or on more than one machine. The third question is whether the date of a typewriting is in harmony with the work of that particular design of typewriter on the date the document bears, or whether the machine on which it was written was actually in existence on the date it bears. It has been shown in numerous cases that a disputed document was written on a machine that was not in existence on its alleged date. It is difficult to imagine proof more conclusive that a document was not genuine.

This last question, and the others referred to above, have arisen in numerous cases, and the American law reports now contain quite an extended list of cases in which the identification of typewriting was the important question in the case. One of the most recent cases of this kind was tried at Saginaw, in the State of Michigan, in October last. The case involved a claim based on a typewritten document which purported to have been written in 1880, and if successful the claim would have amounted to more than a million of dollars. The case was carefully prepared, and on the third day of a trial which it was expected would last three or four weeks, a specialist was called as a witness who so conclusively demonstrated that the document could not have been typewritten on its date, and that the signatures were not genuine, that the opposing counsel, on their own volition, went to the presiding judge in the case and admitted that they were convinced that the document was fraudulent and that they would consent to the issuing of a decree to that effect. It was conclusively proved in this case that that document in dispute could not have been typewritten until at least thirty-one years after its date. This same result in actual trials has occurred in at least three different states, and many cases have been withdrawn from court after the facts regarding the typewriting had been discovered and shown.

ALBERT S. OSBORN in *Discovery*, Vol. VI, p. 455.

18. New Light on a Milton Mystery

Among the treasures of the King's Library in the British Museum is a little volume of the first edition of Milton's earlier poems, published in 1645, which some fifty-eight years ago was the cause of a remarkable literary controversy now almost forgotten. In 1868 Henry Morley (Professor of Literature in University College, London), discovered some verses written on the final blank leaf of this book, and on 16th July of that year wrote a letter to *The Times* to the effect that he had discovered an unpublished poem by Milton.

"The handwriting on this blank page," he says, "to anyone familiar with the collection of facsimiles in the late Mr. Sotheby's 'Ramblings in the Elucidation of the Autograph of Milton' would, I think, convey at first glance the impression it conveyed to me, that this was the handwriting of John Milton. It proved to be a transcript of a poem in fifty-four lines which Milton, either for himself or for some friend, had added to this volume. It is entitled *An Epitaph*,

and signed by him 'J. M. O'ber, 1647.' He was then in his thirty-ninth year."

Morley's claim did not long remain unchallenged, for Masson, an even greater authority, wrote to *The Times* (21st July, 1868), that he was already familiar with this poem, and had formed the opinion that the internal evidence was against its being by Milton, but that in his view the question of the handwriting would be conclusive. Referring to the doubtful signature he says, "Though I copied it as 'J. M.,' as Mr. Morley has also done, I find a query attached to my copy whether I was right in making the first letter 'J.'"

With these two authorities as protagonists the students of Milton were divided into two camps. On the one side were those who contended that the similarities of style (apart from resemblances in the writing and the signature "J. M.") were too good for an imitator, and who asked, If Milton did not write the poem who could have written it? On the other side were those who, while admitting some similarities in the writing (which, however, they did not consider conclusive, especially in view of the doubtful initial) and conceding the fact that the metre and much of the imagery and phrasing were characteristic of Milton, yet urged that it was not beyond the power of a skilled imitator with a good ear for rhythm, and that certain features in the poem afforded evidence against its being by Milton.

The controversy in *The Times* continued for several months, each point for and against the authenticity of the lines being fully discussed, often with considerable acrimony, and when at length it died away it left the question at issue still unsettled. Morley's last word on the subject was in the introduction to a volume of Cavalier and Puritan song, "The King and Commons" (1868), where he reiterated his belief that the handwriting was that of Milton, the initials "J. M.," and that even if it were proved that someone else had transcribed the poem, the author was John Milton. . .

Anyone familiar with Milton's early poems cannot fail to be struck by the similarity in phrasing and imagery between some of them and this poem. . .

Numerous instances might be cited to show that whoever wrote *An Epitaph* must have been thoroughly familiar with Milton's conceptions and modes of expression and able to use them with effect. He has also succeeded in catching Milton's characteristic subtle rhythm of alternating lines of seven and eight syllables. In the long-

drawn-out controversy this poem was wildly attributed to other contemporary writers whose names begin with M, such as Henry More, Jasper Mayne, and Andrew Marvell, but the supporters of the Milton hypothesis urged that none of these writers would have been capable of reproducing this distinctive feature of the rhythm. Among the literary arguments brought against the authorship of Milton was the bad grammar in the couplet—

> Infant Nature cradled here
> In its principles appeare.

but this argument loses some of its force now that it has been shown that Milton has made analogous grammatical slips in other poems in manuscript (cf. Candy, *Some New Stanzas by Milton*, p. 81).

A literary objection which carries more weight is the frequent use of the word "its" in the disputed poem. Milton, like other writers of good English of the period, seldom used that pronoun; it occurs only twice in all his better-known poems, and twice in the newly discovered stanzas, and yet it is found no fewer than four times in this little poem of fifty-four lines, and is also used there with reference to personifications, such as Nature, for which Milton commonly used "his" or "her."

It will be seen, therefore, that if the question had to be decided solely on literary grounds the arguments for and against the authorship of Milton would be fairly evenly balanced, but, as Masson pointed out, the handwriting and the signature are the decisive factors. . .

Who Is "P. M."?

The negative results of these attempts to fix the authorship of the poem led me back once more to the initials. It will be seen on reference to the specimens of Milton's initialled signatures that the "M" does not correspond with his usual initial, nor does it agree in formation with the small "m's" in his writing. Direct observation of the first initial under a low magnification indicated that it was probably not "J," but might be "P" or "R." This deduction was carried a stage further by means of the greater differentiation effected by photography with a coloured screen and colour-sensitive plate, and in the prints from the negative it could be distinctly made out that the letter was not "J" but was probably "P." Lastly, by making an enlargement from the negative (for which I am in-

debted to Mr. T. J. Ward), and blocking out with zinc white the marks of the British Museum stamp, the outline of the letter "P" was demonstrated with certainty. This letter "P" is similar in formation to the small "p's" and to the capital "P" in "Psyche" in the poem.

This definite proof that the final initials are not "J. M." but "P. M.," and that they are in the same writing as the text, disposes of the hypothesis that the poem was dictated by Milton and then initialled by him. I have been unable to discover any contemporary writer with initials "P. M." whose writing agrees with that of *An Epitaph*. It is not in the handwriting of Philip Meadowes, who was appointed to assist Milton as Latin Secretary to the Council of State.

The most plausible hypothesis is that some unknown friend or admirer ("P.M.") of Milton, who had considerable poetic skill and a good ear for rhythm, acquired this little volume and wrote in it a prospective epitaph on Milton himself in which he succeeded in catching not only the poet's style and metre, but also the spirit of his poetry.

I may add that Mr. Candy, who is probably more familiar with the writings of Milton than anyone now living, agrees with my conclusions.

C. Ainsworth Mitchell, M.A., F.I.C., in *Discovery*, Vol. VII, pp. 79 *f.*

Special Question

What items in this example do you regard as internal, and what items do you regard as external, evidence? List each.

CHAPTER X

MISCELLANEOUS EXAMPLES

In this chapter are brought together a number of composite, miscellaneous examples in which illustrations of the methods we have already considered separately may be found.

A number of the examples are sketches of the development of a theory or law or explanatory principle from its relatively crude beginnings as a working hypothesis to its final refinement and establishment. These are included so that students may come to realize the extent to which one scientist builds on the work of his predecessors in the field in which he is doing his research. Most of the really great discoveries have been made by scientists who had the widest comprehension and the deepest understanding of the entire field of knowledge within which the discovery was made. The moral of this is that any young man or woman who aspires to become a scientist should begin by mastering in detail the extant knowledge of the field in which he or she plans to specialize. And the best way to do this is to subject one's self to the discipline of a long course of study, under the direction of teachers and scientists who are themselves doing original research and making real contributions to the body of scientific knowledge.

WHAT TO DO WITH THE EXAMPLES

1. Pick out of each example every illustration you can find of any of the methods discussed above, and tell why you think what you have selected is an illustration of the method you say it illustrates.
2. Make an outline or abstract of the reasoning in each example with a view to bringing out the main stages in the development of the particular bit of knowledge embodied in the example.
3. Name the science from which the example has been selected.

1. The Discovery of Tularemia

I

Tularemia occurs in nature as a very fatal bacteremia of various rodents (especially rabbits) and is due to *Bacterium tularense;* it is transmissible to man as an accidental infection by the bite of an infected blood-sucking insect or tick, or by the lodgment on his hands of the blood or internal organs of an infected rodent, as in the case of market men, cooks, hunters or laboratory workers.

Among the few diseases of man that have been discovered in the last fifteen years is tularemia. It is the only disease of man that has been elucidated from beginning to end by American investigators alone. These investigators have worked in widely separated states, and in most instances each made his first contribution while in ignorance of the work of the others. . . .

In consequence of these circumstances, a variety of names or synonyms sprang up, according to the conditions under which the disease was first encountered by each investigator, and we find plague-like disease of rodents, deer-fly fever, *Bacillus tularense* infection of the eye, rabbit fever and glandular type of tick fever.

Plaguelike Disease of Rodents.—McCoy, in 1911, described what he called a "plaguelike disease of rodents," prevalent among the California ground squirrels but first observed in squirrels from Tulare County, California. McCoy and Chapin, in 1911, discovered the causative organism and named it *Bacterium tularense,* after the name of the County. Tulare County was so named because that region was once covered with marshy beds of the reed tule, a large variety of bullrush. . . .

Deer-fly Fever.—In Utah, the disease in man was for several years popularly known as "deer-fly fever" owing to the belief that the infection was due to the bite of the blood-sucking fly *Crysops discalis* commonly found on horses. This belief found expression in a paper published by Pearse, in 1911, in which he described six cases, which constitute the first reported human cases of tularemia differentiated clinically.

Belief in the agency of the deer-fly was crystallized into demonstration in 1919 and 1920, when I isolated *Bacterium tularense* from seven human cases and seventeen jack rabbits in Utah, and named the disease tularemia; Mayne and I proved the deer-fly *Crysops discalis* to be a transmitter of the infection in laboratory animals.

So slow had been the diffusion of printed knowledge on this subject from California to Utah, or from Utah to California, that it required ten years for the identity of the California rodent disease and the Utah human disease to become recognized.

Bacillus Tularense Infection of the Eye (Vail, 1914, Sattler, 1915, and Lamb, 1917).—Three cases of tularemia occurred in the practices of three ophthalmic surgeons of Cincinnati. The bacteriologic diagnosis in these three cases was made by Wherry and Lamb, who isolated *Bacterium tularense* on culture medium from guinea-pigs into which eye scrapings had been injected. They also isolated the organism from two dead wild rabbits collected in nature near the residence of Sattler's patient. Vail's case is the first human case of tularemia on record to be diagnosed bacteriologically.

Rabbit Fever.—A man (E. N.) working in the Washington, D. C., market went to his physician, Dr. J. Lawn Thompson, in 1921, for treatment for what he informed the physician was "rabbit fever," adding that "rabbit fever" was well known among market men. Examined in the Hygienic Laboratory the patient's serum was found to contain *Bacterium tularense.*

Glandular Type of Tick Fever.—Dr. H. E. Lamb of Gooding, Idaho, in a paper read before the South Idaho District Medical Association, in 1923, used the phrase "glandular type of tick fever" to describe cases which were encountered in practice by himself and Dr. J. H. Cromwell. At that time they considered these cases as a type of Rocky Mountain spotted fever, and added that about ten per-cent of their cases of "tick fever" (fever following a tick bite) had been of the glandular type without eruptions, that the glands in some cases suppurated (produced pus), while in others they did not, and that these patients were very sick and had fever for several weeks.

The interpretation is justified that these cases of the glandular type of tick fever were tularemia, especially since the serum of a similar case sent to the Hygienic Laboratory, in 1924, by Dr. R. M. Johnson of Billings, Montana, contained *Bacterium tularense.*

Parker, Spencer and I, reporting in May, 1924, had demonstrated the infection in the common wood tick of Montana, *Dermacentor andersoni* Stiles, collected in nature from vegetation, and in the heart blood of a snowshoe rabbit; also in ticks collected from the horse, mountain goat, woodchuck, mountain rat and Columbian ground squirrel.

Case histories and notes have been recorded for forty-nine cases,

of which fourteen were caused by fly bite in Utah and Idaho, one was caused by tick bite in Montana; ten patients had cut up jack-rabbits for hog feed, chicken feed and fish bait in New Mexico, ten had dressed wild cottontail rabbits for food in Ohio, Washington, D. C., North Carolina, Virginia and West Virginia, and fourteen were laboratory workers who had performed necropsy on infected guinea-pigs or rabbits in laboratories.

Two clinical types of symptoms are encountered in analyzing these cases.

Of thirty-five cases in which the patients were fly-bitten, tick-bitten, or had cut up jack-rabbits or dressed cottontail rabbits, thirty-three were of the glandular type, with enlarged glands and an evident local site of infection; in only two of the thirty-five was there a record of absence of enlarged glands or absence of a local site of infection.

Fourteen cases of infection of laboratory workers were free from enlarged glands or local site of infection, and to the clinician they simulated typhoid fever and were therefore of the typhoid type. Hence tularemia fever may be classified as glandular and as typhoid.

EDWARD FRANCIS, M.D., in the *Journal of the American Medical Association*, Vol. 84, pp. 1243-1250 (abbreviated and slightly modified).

II

A disease contracted by many soldiers during the World War and known as "trench fever" is strikingly similar to tularemia, as is shown by the following résumé of an account of it given by Major General Sir David Bruce in his presidential address before the Toronto (1924) meeting of the British Association for the Advancement of Science. "One of the interesting examples which the President discussed . . . is that of 'trench fever', which he regarded as one of the 'few diseases of undetermined origin which are slowly emerging from the unknown to the known.' The account which he gave is a striking example of what can be done by systematic and determined research into any disease. In the early days of the war, trench fever was not even recognized to be a distinctive disease, and was confused with typhoid fever, malaria and even rheumatism. When it was observed to have characteristics of its own, attempts were commenced to track the disease to its source. The blood of trench-fever cases was found to be infective, but no germ could

be revealed by the most careful microscopical examination of the blood corpuscles and lymph.

"At length a Trench Fever Committee was formed and research organized, with the result that within six months sufficient was known about the disease to make its prevention a possibility. The germ still remained unknown, evidently because it is of the ultra-microscopic type, but the 'germ carrier' was discovered, in the form of the body louse. This explains why trench fever disappeared with the end of the war and the elimination of the louse. Although the disease germ was not detected in the human body, however, the 'infective agents' were actually discovered in the body of the parasite. These took the form of enormous numbers of very minute bodies—so minute, in fact, that their exact nature is still unknown, although they are regarded as either protozoa or bacteria, which develop in the louse, and pass on to their final stage in man."

Discovery, Vol. V, pp. 240*f.*

Special Questions

1. What are the chief similarities between tularemia and trench fever?
2. What is the chief difference and is it sufficient to disprove the hypothesis that the two diseases are identical?
3. Could one infer by analogy that the two diseases are identical?
4. If the hypothesis of identity were reached by the method of analogy, what would be the crucial test which would verify the hypothesis?

2. The Cause of Yellow Fever

At the close of the Spanish-American War in 1898, Cuba became a ward of the United States, and in the following year the dreaded yellow fever broke out among the American troops stationed there. A commission composed of Major Walter Reed, Dr. James Carrol, Dr. J. W. Lazear and Aristides Agramonte were appointed to look into its cause and transmission.

Like many great discoveries, this one was not made all at once or by one man. Dr. Carlos H. Finley, twenty years before, had advanced the idea that the disease was transmitted by mosquitoes. Major Reed determined to test out this theory, and the only way to do this was to use human beings to try it out on, as animals appeared to be immune. Volunteers were called for and the commission offered themselves too. Every man knew he was likely to die.

Two young soldiers, Privates John R. Kissinger and John J.

Moran, offered their services. Dr. Reed talked with them and told them the danger and suffering involved and said that a money compensation would be made them if the experiment was successful. The soldiers declined the reward, and Major Reed touched his cap and said, "Gentlemen, I salute you." He wrote later in his published account of the experiment: "In my opinion this exhibition of moral courage has never been surpassed in the annals of the army of the United States."

The volunteers permitted themselves to be bitten by mosquitoes that had stung yellow fever patients. Dr. Lazear became ill with fever and died in convulsions. Dr. Carroll almost died, and for three days his life hung in the balance. The experiment was tried on eleven other men and nine of them came down with yellow fever.

There were some who did not think this was definite proof. A lonely hut was constructed, far away from habitations and divided into two parts by wire screens. The entire building was also covered with screens. Two susceptible men were put into this house, one in each compartment, and were thus subjected to the same conditions. Both lived there a while and remained perfectly healthy, showing there was no infection.

Then Major Reed let fifteen infected mosquitoes fly into one of the compartments. The man in the mosquito infested compartment was bitten fifteen times. In four days this man had yellow fever and the other one separated from him only by a screen remained perfectly well.

The mosquitoes were removed and soldiers were placed in each compartment. They remained well. There were still sceptics who claimed that infection might yet be by contact. Major Reed devised conditions which absolutely disproved this theory and showed that it could only come from direct infection of blood from a yellow fever patient, or by an infected mosquito bite, which he said was the same thing.

Once the cause was known, it was possible to stamp out the disease. The effect of this event on history and world progress has been revolutionary. The Panama Canal became a possibility and shorter trade routes were open to all the ships of the world. Plague ridden ports of Latin America were cleaned up and large areas were made habitable.

Daily Science News Bulletin, No. 243A.

3. Super-X-Rays Latest in Work Begun by Newton

About two hundred and fifty years ago, the great English scientist, Sir Isaac Newton, performed an experiment which started a new field of research. In his *Opticks,* the first edition of which was published in 1704, he thus described what he did: "In a very dark Chamber at a round hole about one third part of an Inch broad made in the Shut of a Window I placed a Glass Prism, whereby the beam of the Sun's Light which came in at that hole might be refracted upwards toward the opposite Wall of the Chamber, and there form a coloured Image of the Sun." This was the first artificially obtained spectrum to be studied by science, and, according to the theory proposed by the Dutch physicist, Christian Huyghens, before the French *Academie des Sciences,* it was due to the fact that light consists of waves.

These waves, or vibrations in the ether, are much like waves in water, and the wave theory, which was not generally accepted until about a century ago, states that waves of different colors vibrate at different rates. The deepest red light that we can see vibrates about 375,000,000,000,000 times a second, while the violet light vibrations are about twice as fast. But these are not the only kinds of radiations that exist. Vibrating more slowly than the red are the so-called infra-red, or heat, waves, which are copiously emitted by hot bodies and may be detected by such an instrument as the radiometer, invented by Sir William Crookes, often used as an ornament in optician's windows. On the other side of the visible spectrum are the ultra-violet rays, which vibrate more rapidly than the violet. These affect the films in our cameras, and also tan our skins, for it is their presence in sunlight that causes sunburn.

For many years this represented the extent of the known spectrum of radiation, but in 1888, Prof. Heinrich Hertz, at the University of Bonn, in Germany, discovered that if an oscillating electric current was discharged across a gap, it gave rise to what were later called Hertzian waves, in his honor, and which, in the hands of Marconi and others, made modern radio communication possible. The fastest vibrating of these have a frequency of about 450,000,000,000 per second, while the ones used in intercontinental wireless telegraphy vibrate as slowly as a hundred a second, and the waves may be a mile or more in length. Still longer ones could be produced if they were of any particular advantage.

The extension of the known spectrum in the other direction,

among the rays of shorter wave length, or higher frequencies, than those in the ultra-violet began in 1895, with Wilhelm Konrad Roentgen, at Wurzburg, Germany. He noticed that when he operated a Crookes tube, named after Sir William Crookes, its inventor, and consisting of a glass bulb exhausted of air in which a powerful electric discharge could be made, a nearby card coated with a special chemical preparation became luminous. He also noticed that the rays from the tube, which he called X-rays, because he did not know their nature, were stopped by solid objects like lead and iron, but were able to pass through wood and flesh. In 1912, Dr. Max Laue, of Zurich, proved that these Roentgen rays are the same as light, vibrating more rapidly, and of much shorter wave length. Their frequency, or rate of vibration, may be as great as 25 billion a second, and their waves as short as a twenty-five billionth of an inch.

The discovery of these rays led Henri Becquerel, at Paris, to suspect that some similar sort of rays might be given off spontaneously from matter, and he found, in 1896, that actual rays, able to affect a photographic plate even when wrapped in black paper, were given off from the mineral pitchblende. Two years later, in 1898, Pierre and Marie Curie discovered radium in this mineral, and the rays discovered by Becquerel are now known as the gamma rays of radium. The slowest vibrating are identical with the X-rays of the highest frequency, while some vibrate as fast as several hundred billion a second. But even this was not the limit, for the new cosmic rays discovered by Prof. Millikan compare with the X-rays as the X-rays themselves compare with light, and the study begun with the simple experiment of Newton is ably carried on.

James Stokley, Science Service staff writer, in *Daily Science News Bulletin,* No. 242A.

4. Cosmic Rays

As early as 1903 the British physicists, McLennan and Rutherford, reported that the rate of leak of an entirely enclosed electroscope could be reduced as much as 30 per cent, by surrounding it with walls of iron or lead a couple of inches thick. This proved that the normal leak of an electroscope is due in part to rays that are able to pass through a centimeter or more of lead and then ionize the gas inside of the electroscope. The rays having this property were therefore called "the penetrating radiation of the atmosphere,"

and were at first assumed to be due to radioactive materials in the earth and atmosphere, and this is in fact the origin of the greater part of them.

In 1910, however, Gockel, a Swiss physicist, took up electroscopes in a balloon to a height of 13,000 feet, and reported that he found "the penetrating radiation" about as large at this altitude as at the earth's surface despite the fact that if the rays had their origin in radioactive materials in the earth and in the atmosphere they would have been expected to show a decrease with altitude. Between 1911 and 1914, Hess, another Swiss physicist, and Kolhorster, a German physicist, repeated these balloon measurements of Goekel's, Kolhorster ascending to a height of 9 kilometers, or 5.6 miles. Both men reported that they found the penetrating radiation decreasing a trifle for the first mile or so, and then increasing until it reached a value eight times as great as at the surface. This seemed to indicate that the penetrating rays came from outside the earth and were, therefore, of some sort of cosmic origin. If so, it was computed from the Hess and Kolhorster data that the hypothetical rays would have to produce in an enclosed electroscope sent to the top of the atmosphere an ionization at least forty times as great as at the earth's surface.

In 1915 I made plans to test this point by sending up electroscopes to as near the top of the atmosphere as we might hope to come, but on account of the war it was necessary to postpone further plans in this direction. In the fall of 1921, however, Mr. I. S. Bowen and myself designed, with the aid of the instrument maker, Mr. Julius Pearson, some electroscopes that we succeeded in sending up from Kelly Field, Texas, in the spring of 1922 to altitudes of 15.5 kilometers, or nearly 10 miles. Our results agreed with those of the European observers in indicating a larger ionization inside our electroscopes at high altitudes than at low, but they proved conclusively that the intensity of ionization at high altitudes was not over one-fourth that which had been predicted from the Hess-Kolhorster data. This meant that the rays of cosmic origin, if they existed, were very much harder or more penetrating than the European observers had imagined, or else that the observed ionization was due to materials of some sort existing in the atmosphere itself, in which case it would presumably be of ordinary radioactive origin and hence have the absorption coefficient of ordinary gamma rays.

Accordingly, Dr. Russell Otis and myself, in the summer of

1923, carried 300 pounds of lead and a tank of water to the top of Pike's Peak. These Pike's Peak experiments showed that it was hopeless to attempt to obtain crucial tests as to the existence or non-existence of these hypothetical cosmic rays unless we could go to very high altitudes. The only test which we could think of was to be found in sinking our electroscopes to various depths in snow-fed lakes situated at very great altitudes.

During the summer just past, Mr. G. Harvey Cameron and myself made somewhat elaborate preparations for making such tests, going first to Muir Lake (altitude 11,800 feet), a beautiful, very deep, snow-fed lake just under the brow of Mount Whitney, the highest peak in the United States. We sought a snow-fed lake because our own preceding underwater experiments had been vitiated by our discovery that the waters were radioactive. The results of our summer's work were, very briefly, as follows:

At the surface of Lake Muir our electroscopes showed a (definite) rate of discharge. As we sank the electroscope to greater and greater depths this rate decreased continuously down to fifty feet, after which it became constant. This meant that we had obtained thoroughly quantitative evidence for the existence of an extraordinarily penetrating radiation, so hard that, if it came from outside the atmosphere, it required the equivalent of more than six feet of lead to absorb it entirely.

To get crucial tests as to whether the hard rays were of cosmic origin or not, we next went to another very deep snow-fed lake, Lake Arrowhead, in the San Bernardino Mountains, 300 miles farther south, which has an elevation of 5,125 feet. The atmosphere between the two elevations has an absorbing power for any very penetrating rays equal to about six feet of water. If the rays that we observed at Muir Lake all came in from above, and if there were no rays at all generated in the atmosphere between the two lakes, we expected to find that each electroscope reading at a given depth below the surface in Arrowhead Lake would be the same as the reading at a depth six feet farther down in Lake Muir, the atmosphere between acting merely as an absorbing screen, and as a matter of fact in both our electroscopes we did find this prediction very beautifully verified. Our proof, therefore, is now quite definite that there is an extraordinarily hard radiation coming into our atmosphere from outer space. Further, since at all the altitudes at which we have experimented we find no measurable variation in the intensity of these rays at any time between mid-day and mid-

night, we conclude that these rays shoot through space equally in all directions.

By the use of a formula of probable, though not of certain reliability, we find that our hardest observed rays have a frequency at least fifty times that of the hardest gamma ray, a thousand times that of the average X-ray, and about ten million times that of ordinary light. Our experiments further showed that these rays of cosmic origin are hardened as they go through the atmosphere, just as X-rays are hardened in going through lead, and thus we infer that we are working with a region of spectral frequencies about an octave in width and ten million times above the octave of optical frequencies to which our eyes respond.

R. A. Millikan in the *Scientific American*, March, 1926, as quoted in the *Literary Digest*, March 13, 1926, p. 23.

5. Lead Changed to Mercury

That elements can actually be transmuted and one metal can be converted into another seems demonstrated by experiments reported to the British scientific journal, *Nature*, by Dr. Arthur Smits and Dr. A. Karssen, of the University of Amsterdam. Lead has, under the influence of the electric current in a quartz lamp, been changed into mercury and perhaps into thallium, according to the claims of these two scientists. We read in Science Service's *Daily Science News Bulletin* (Washington):

The Dutch experiments tend to support the claims of Professor A. Miethe of the University of Berlin and Professor Hantaro Nagaoka, of the Tokyo Imperial University, that they have changed lead into gold. When their claims were first made, many scientists doubted that such a change could be effected without the use of vast amounts of energy, far more than any of these modern alchemists have used.

One of the first to claim that he had solved this ancient puzzle was Professor Miethe, who, in 1924, announced the result of experiments with a mercury-vapor lamp, similar to that giving the violet light often used in photographic and movie studios, in which an electric arc operates in vapor of mercury. He was assisted in this work by Dr. H. Stammreich, and in one series of experiments the lamp was operated for 197 hours with a current of about the same order as that used in lighting our homes. Though the mercury was shown free from gold at the beginning, slight traces of yellow metal,

less than three ten-millionths of an ounce, were found at the end. Minute as such an amount is, delicate chemical tests can detect it, and the tests in this case were made by Dr. Fritz Haber, considered one of the greatest of German chemists. In later experiments, Dr. Miethe claimed that he had obtained the gold in much larger quantities, enough to test by the ordinary laboratory methods, but not enough to make the method commercially practicable.

According to modern conceptions, the atoms of which all matter is made consist of a nucleus made up of what are called protons, around which revolve a number of electrons, much as the planets revolve around the sun. The outer electrons, in fact, are referred to as "planetary electrons." The difference between elements, according to this theory, is due only to the electrical charge of the nucleus and the number and arrangement of the planets. In the case of elements like radium, the atoms break apart spontaneously with the liberation of helium, whose atom is the simplest known next to hydrogen.

Theoretically, then, it seems easy to change the atoms by merely knocking out some of the planets, but this does not affect the nucleus. Dr. R. A. Millikan, of the California Institute of Technology has thus obtained what he calls "stript atoms" of some elements, in which the outer ring of planets has been removed, but this does not radically alter the elements.

To break into the nucleus, the central "sun" of the atomic solar system, would require, in the opinion of many scientists, vast amounts of energy. Since mercury is next to gold in the procession of the elements, the removal of a single charge, corresponding to the complete nucleus of hydrogen, which is the simplest of the elements, would convert mercury to gold. But the nuclei of other elements have been bombarded with an energy corresponding to five million volts, with no sign of disintegration.

Now it seems, however, that comparatively small amounts of energy are able to get in where larger amounts have failed, and the work at Amsterdam is taken as confirming the atomic theories. The method of the Dutch scientists, however, was slightly different from that used by Miethe and Nagaoka, for instead of mercury they used lead, its close relative. The lead was melted and the tube filled with its vapor. Though the lead was free from mercury, as demonstrated by the fact that spectral photographs of the light from the tube showed only the lead spectrum, after a current of 60 to 100 amperes had been passed through it in the form of successive sparks

for a time, the lead spectrum gradually began to disappear. Instead of the lines indicating this element, those of mercury gradually appeared on the plate, together with those of thallium, a rather rare metal which lies between lead and mercury in the list of the elements.

Tho the lead spectrum almost completely disappeared, "this does not prove the transmutation to be strong," Professor Smits reports, "as it is known that a small quantity of mercury can cause the spectrum of another element to disappear. But at all events, our spectra show in a very convincing way the transmutation of lead into mercury."

The presence of this synthetic mercury was confirmed by a chemical test, for when iodin vapor was passed through the tube containing the product of twelve hours of sparking, the familiar red color of mercury iodin appeared.

Literary Digest, March 27, 1926, p. 74 (*cf. Discovery,* Vol. V, p. 247).

6. Right- and Left-Handed Fossils

A fossilized skull recently found in London has been pronounced by Professor G. Elliot Smith of University College to be that of a left-handed woman. This statement has given rise to widespread incredulity, and even derision. Later, Professor Smith pointed out the definite evidence, provided by the skull, of the reversal of the normal asymmetry of the brain case, and the reasons for associating this reversal with the condition of left-handedness. He now writes as follows in *The British Medical Journal* (London):

"In the winter of 1907-08 Professor Wood Jones and I investigated the significance of this reversal, accepting as the criterion of right- or left-handedness, respectively, the observation whether the right or the left humerus was the longer and stronger. In the cranium I found that the impressions upon the bone were reversed in those cases where the left humerus was longer and more robust than the right.

"The question has been raised by several critics as to the validity of these inferences from the size of the humeri as indications of right- or left-handedness. Since 1845, when Arnold raised this problem for consideration, an extensive literature has accumulated from repeated discussions. An admirable summary by the late Professor Gaupp was published at Jena in 1909. He summarizes the researches on the question of the excess in length of the left or right arm, and shows that these differences are usually associated with

left- and right-handedness, respectively. However, he calls attention to the fact that at the time of birth the length of the bones in the two arms is identical. Occasionally it happens (in people whose occupation compels them to exercise the left arm more than the right) that a person with a congenital tendency to right-handedness may have longer and stronger bones in the left arm. This is altogether exceptional, and should not be allowed to discredit the clear inference from a large mass of evidence that the length of the arm-bone in the great majority of cases is a safe indication of right- or left-handedness.

"During the course of his work in Nubia in 1907 Professor Wood Jones attempted to correlate his observations on the skeletons of the ancient inhabitants of Nubia with the conditions found in living Egyptians, and he discovered that in right-handed living people the left clavicle was longer and thinner than the right. Then, proceeding to examine the bones in the skeletons, he found in those cases where the right humerus was longer and stronger than the left that the left clavicle was longer and thinner than the right. Moreover, he found that when the condition was reversed the left humerus was then the bigger bone. He regarded this as a confirmation of the use we had made of the humerus as an indication of right- or left-handedness.

"The asymmetry of the brain associated with this asymmetry of the limbs is not restricted to modern man. It is characteristic of the human family as a whole, and it seems to be one of the distinctively human traits revealed in most of the known fossil material. The asymmetry of the brain is as old as the human family itself, and is a fundamental character distinguishing man from all other members of the order Primates.

"Attempts have been made in the past to determine whether extinct members of the human family were right- or left-handed, by a study of the implements made by these people. But so far as I am aware no one has attempted to solve this problem directly by a consideration of the fossil remains of man himself. The evidence of asymmetry of the brain to which I have called attention throws a light on this problem that is much more reliable than any inference which can be made from man's handiwork.

"The question naturally suggests itself whether there is any trace of asymmetry in the anthropoid apes. Altho the two cerebral hemispheres in the apes are approximately symmetrical, some interesting facts suggest the remarkable conclusion that the bones of

the right arm are longer than those of the left arm in the gibbons and orangs (as in man), but the bones of the left arm are the longer in the chimpanzees and gorillas. Tho there is no obvious asymmetry of the brain, there seems to be in the anthropoid apes an instability that affects the symmetry of the limbs, altho neither the right nor the left is so definitely selected as in the case of the vast majority of human beings.

"It is of some interest to note that B. S. Parson, in his book *Left-handedness* (1924), came to the conclusion that the ocular dominance —that is, the use of one eye for fixation—determines both cerebral dominance and the "handedness" of the individual.

"In all these discussions it must be remembered that even if the right- or left-handedness does not make its appearance until well on in the first year of life, it is due to congenital tendencies that manifest themselves at this relatively late time. It must also be remembered that these congenital tendencies may in many cases be overcome to a considerable extent by training; so that it is possible to get a brain showing the asymmetry distinctive of left-handedness with limbs which show the conditions usually associated with right-handedness."

Literary Digest, February 27, 1916, p. 74.

7. Wireless and the Upper Atmosphere

When Marconi had completed his first successful experiments, which showed that the electric radiations discovered by Hertz could be used as a means of communication over considerable distances, and finally in 1902 succeeded in bridging the Atlantic, attention was immediately directed to the problem of establishing the theoretical laws governing the radiation of wireless waves over the earth's surface. The results of this analysis indicated that the spherical form of the earth, intervening between the transmitter and receiver, should—in spite of diffraction—be too great an obstruction to enable communication to be established at all over long distances.

Here then appeared an uncomfortable divergence between theory and experiment but, owing to the lack of accurate measurements and to certain complications of the theory, which produced considerable divergence of opinion among the many eminent mathematicians at work on the problem, the exact extent of the discrepancy was not at all certain. It was necessary to wait, on the experimental side, until 1909, when Austin made a large number of measurements

on the strength of signals received at various distances from a fixed transmitter, and on the theoretical side until 1912, when Professor G. N. Watson, after a critical examination of the results of other workers both theoretical and practical, produced a satisfactory and generally accepted theory of the propagation of wireless waves over the earth's surface. Austin's experimental results emphatically confirmed the existence of the discrepancy when compared with Watson's theoretical values, and all subsequent measurements made since over long distances lead to the same conclusion. In some cases the intensity measured is a million times greater than that which theory would predict.

Nothing remained but the virtual certainty that one or more of the assumptions made by the theorists was invalid. Apart from those underlying Maxwell's electromagnetic theory—for these one would refrain from questioning at least until the last resort—the only important assumption made, which could not be verified by simple experiments, was that the earth's atmosphere had the properties of a homogeneous and perfect dielectric.

It is true that those parts of the atmosphere which we can explore, that is, to about ten miles up, are known to satisfy this assumption well enough. But of the vast regions above this, into which the highest sounding balloon has never penetrated, we know little or nothing. It is natural, therefore, that speculation should turn to this part of the atmosphere to find a cause for the unexplained phenomena of long-distance transmission by wireless.

As early as 1900, in fact, Oliver Heaviside put forward a tentative hypothesis which is sufficient to account for the discrepancy. He postulated that the atmosphere at heights of the order of 60 miles is highly ionised owing to the extreme attenuation of the gases, coupled with the much greater ionising power of the sun's rays to be expected at such heights; and that this highly ionised part of the atmosphere forms a conducting medium which is bounded on its lower side by a fairly well-defined surface. At this surface, therefore, wireless waves arriving from below would be reflected or refracted, and thus returned to earth. The consequence of such a state of affairs is easily seen; for the waves, instead of escaping from the earth, would be confined in a comparatively narrow space between two concentric surfaces (that of the earth also being of good conductivity). Thus concentrated, the waves would naturally arrive at any given spot—sufficiently far from the transmitter for the upper layer to have full effect—with much greater intensity than if the layer

did not exist; for, in addition to concentrating the energy, it would be the means of enabling the waves to bend round the curve of the earth.

Within the last few years the "Heaviside layer" theory has come into very great prominence, for the natural course of development of wireless telegraphy has brought to light a number of new and striking phenomena which cannot be explained without it. . . .

Those who attempt to listen in to a distant broadcasting station say, 100 miles or more away, have all now become familiar with the phenomenon known as "fading"; that is, the curious and rapid fluctuations in the intensity of the signals received. At one moment they may become faint and scarcely audible, at the next they will swell to an intensity rivalling that of the local broadcasting station itself. If, on the other hand, the same station is "tuned-in" in the middle of the day, it will be found that either it is impossible to pick up the station at all, or its intensity will remain quite steady. This phenomenon, though it will probably long be a serious hindrance to long distance broadcasting, is of particularly scientific interest, since it supports strongly the theory of a reflecting layer in the upper atmosphere. In the first place, it is almost beyond doubt that no change takes place at the surface of the earth between day and night which could possibly cause a steady day intensity to change to a fluctuating night one, and in the second place, we know of no variation whatever in the physical state of the earth or known part of the atmosphere which could possibly bring about the rapid fluctuations in intensity characterizing the phenomenon.

We are then forcibly driven to look for the cause in the upper atmosphere, and the Heaviside layer supplies us with one. For if there are waves which travel from transmitter to receiver by an upper route as well as a direct wave travelling over the earth's surface, we have all that is necessary to give rise to the phenomenon of optional interference, that is, the adding or subtracting of the two waves according to their relative phases. Further, since we have no reason for denying the possibility of rapid changes taking place in these upper regions, we may suppose that the rapid fluctuations known as "fading" are due to interference effects produced by variations in the phase or intensity of the upper wave relative to the direct wave.

But broadcasting has led, if indirectly, to other interesting developments supporting the idea of an upper reflecting layer. The monopolization by broadcasting stations of the lowest band of wavelengths hitherto in use has driven the experimental amateur to yet

lower wave-lengths on which there had been little or no experience under modern conditions. These short wave-lengths, though accepted somewhat grudgingly by the amateur as the leavings of the more powerful interest, have proved to them veritable blessings in disguise.

No sooner had this allocation been made than rumours of unusually large ranges obtained by amateurs on certain occasions were current. Organized by amateur societies, a determined attempt was made to verify them and test the capabilities of the new wave-lengths. This led first to the successful establishment of communication across the Atlantic by many amateurs in 1921, and finally, in 1924, to the exchanging of messages between amateurs in England and their associates in New Zealand, employing in some cases the very modest amount of power of only 12 watts—an amount which it was believed by many would not suffice to carry more than a few miles.

This truly astounding result seems hardly yet to have been realized. To work satisfactorily over a mere 2,000 miles, it has hitherto been found necessary to erect a station with an output of five hundred kilowatts and pass into the aerial a current of some 500 amps. Yet we now have amateurs working to each other across half the world every day with less than one ten-thousandth of this power and with the feeble aerial current of perhaps ¼ amp. in the aerial. It must be added, however, for a full understanding of the situation, that short-wave communication over these long ranges with such low power is decidedly freaky—in fact, it is usually only possible at all during a very few hours in the twenty-four. What is important here is that its possibility places it beyond question that the signals travel through the upper atmosphere and not along the earth's surface. It is well known that waves of this length when travelling along the earth are reduced to an insignificant fraction in a very few miles (hence the reason that they have so long been considered of little or no use). An upper travelling ray is therefore the only possible way of explaining how it is they manage to escape being absorbed by the earth. . . .

R. H. Barfield, M.Sc., in *Discovery*, Vol. VII, p. 62.

8. The Aurora Borealis or Northern Lights

Until recently there has been no satisfactory explanation for the phenomenon known as the Aurora Borealis, or the Northern Lights. For a long time they were regarded as the specter of a hypothetical

gas, a tenuous mixture of hydrogen and helium, which was assumed to exist in the upper atmosphere. The gas was called *Geocoronium*, because the spectrum bore a close resemblance to the spectrum of the sun's corona.

In the winter of 1912 Lars Begard, Professor of Physics at the University of Christiania, made a special photographic investigation of the Northern Lights. He came to the conclusion that the pale blue and violet rays were due to nitrogen that was being bombarded by electric rays emitted by the sun. But the spectrum also had a darker green line for which he was unable to account.

Aided by a subsidy from the Norwegian Government, he again took up his work, which involved elaborate and expensive research. He succeeded in identifying at least thirty out of thirty-five lines in the spectrum as being due to nitrogen, so that the Geocoronium theory could be abandoned. He found that the green line reached its greatest intensity nearest the earth, but its true nature remained a mystery.

As he could not conceive that nitrogen gas of sufficient density could exist at such a height as to produce a luminosity so brilliant as the Aurora Borealis, he came to the conclusion that the nitrogen was not present in the form of a gas but in the form of a fine dust made up of infinitesimally minute crystalline particles that were kept suspended by electric charges.

The temperature one or two hundred miles above the surface of the earth approaches the absolute zero or 273 degrees Centigrade. In such a temperature tenuous nitrogen would condense into crystals, such as those imagined by Begard.

To find confirmation of his tentative assumptions, Begard tried to reproduce artificially the conditions on which they were based. He went to Leyden and worked in the famous laboratory of the Dutch scientist, Heike Kamerlingh Omnes, a winner of the Nobel Prize, who in the year 1908 succeeded in liquefying helium at a temperature of 271.95 deg. Cent.

Nitrogen freezes at 210 degrees Cent. With the help of liquid hydrogen Begard was able to reach this temperature, and produced a thin plate of solid nitrogen. He subjected this plate to cathode rays of varying swiftness, and found that with a certain swiftness the spectrum was identical with that of the Northern Lights. Even the green line, which may now be taken as characteristic of the solid nitrogen spectrum, was present.

Adapted from the *Literary Digest*, April 19, 1924, p. 82.

At first this seemed conclusive, but Professor McLennan, director of the Physics Laboratory at Toronto, the only other laboratory in the world possessing such equipment for low temperature investigations, repeated Begard's experiment, with the assistance of Dr. G. M. Shrum. He found the green color, but as he used a more powerful spectroscope than had Begard, also found that it did not agree with the line in the Aurora Borealis. The line in the spectrum obtained from the solid nitrogen turned out to be double, with one part on one side, and the other on the other side of the green line in the Aurora Borealis spectrum.

In his latest work, Dr. McLennan has been able to reproduce the line artificially, in precisely the same place as it occurs in the natural aurora. As helium is so light, he supposes that the atmosphere at an altitude of sixty miles would contain a large proportion of it, so he passed the cathode rays through a partly exhausted tube containing about twenty-five parts of helium to one of oxygen. The line was obtained, even though the use of oxygen or helium alone did not show it. Thus, the origin of all the observed colors in the Northern Lights is known, and even more important evidence is obtained as to the composition of the upper atmosphere. The Heaviside layer, supposed to consist of ionized gases which reflect radio waves back to the earth instead of going out in space to be wasted, may consist largely of helium, and the Northern Lights study may lead to a better understanding of one of the greatest mysteries of radio.

Another link in the chain of discoveries which led to the unraveling of the mystery of the Aurora Borealis should be mentioned. A number of years ago, the English physicist, Sir William Crookes, produced what are called cathode rays by passing a high-voltage electric discharge through a tube from which the air had been exhausted. These are now known to be rapidly moving electrons, the minute electrical charges of which the atoms of matter consist. As some of these phenomena appear very much like the Aurora Borealis, it was suggested that cathode rays were being emitted by the sun and that when these encountered the gases in the upper atmosphere of the earth, auroras were produced. In confirmation of this hypothesis, a Scandinavian scientist, Professor Kristian Birkeland, placed a magnetized sphere representing the earth in a vacuum, and when he bombarded it with cathode rays, artificial auroras appeared.

Adapted from an article by JAMES STOKLEY
in *Daily Science News Bulletin*, No. 236B.

9. Do Two and Two Make Four?

If one hydrogen atom weighs 1.008, how much will four of them weigh? From what we have been taught at school we should answer 4.032, but it seems that this is wrong. For four hydrogen atoms go to make up one atom of helium, and that weighs just 4 and no more. . .

In 1815 a man named Prout suggested that all the elements were made up out of the lightest element of them all, that is, hydrogen... If so, all the atomic weights would be simple multiples of the atomic weight of hydrogen, and if that were taken as the unit, then all the atomic weights would come out handy whole numbers with no vulgar fractions left over. A scientist hates fractions as much as any school-boy. Carbon would then be just 12, oxygen would be just 16, and so on through the list. It was a fascinating idea and seemed likely, for most of the elements were pretty nearly whole multiples of hydrogen, and it was naturally suspected that the fractional atomic weights in the list might be due to erroneous determinations.

So the chemists set about the more exact determination of the weights of all the elements in the hope that they would come out nice and even. But it did not turn out as they hoped. On the contrary, the more careful they were with their weighing the more it became evident that hydrogen was not contained in the other elements an even number of times. It seemed, then, that Prout's hypothesis would have to be given up and that it could not be held that all the other elements were built up of hydrogen atoms.

For it was firmly believed up to the end of the nineteenth century that matter was indestructible, however much it might change its form. You can make carbon disappear, as you do when you burn coal in a grate, but if you should catch all the invisible gases that go up the chimney you would find that the carbon in the gases weighed just as much as the original coal. This was called the law of the conservation of mass. There was another law, the twin of this and regarded as equally absolute, the law of the conservation of energy, that energy also could neither be increased nor diminished although its form might be changed, as when we convert electrical energy into light and heat in the incandescent bulb.

The most exact weights and measurements confirmed these two laws. They do yet, for that matter. There is no direct experimental

evidence to the contrary. But we do not nowadays regard them as so absolute as we used to suppose. We find apparent exceptions on both sides, and so we are coming to the conclusion that matter and energy are in some cases interchangeable. For instance, it is found that light, once regarded as wave motion in an immaterial ether, exerts a kick when it leaves a shining body and a push when it strikes an opaque body. Light, then, has inertia like matter. It seems to have weight, too, for Einstein has shown that a beam of starlight is attracted by the sun as it goes by.

In 1915, the centennial of Prout's hypothesis, Professor W. D. Harkins of the University of Chicago showed that after all the so-called atomic weights gave evidence in themselves that all *true* atomic weights are whole numbers, and this has become the famous whole-number rule upon which much of our modern atomic theory is now based. According to Harkins's theory all atoms are built of hydrogen, just as Prout supposed, but most of the hydrogen is first built into helium, in which process about 0.8 per cent of the mass seems to be lost but actually escapes as energy; and, surprising enough, the theory indicates that if one pound of hydrogen could be converted into helium, as seems to happen in the sun and the stars, as much heat would be given off as in the burning of ten thousand tons of coal, enough heat to warm a small dwelling for a thousand years.

This leads directly to the startling conclusion with which I began. For if the atomic weights of all the other elements are nice round numbers and if the atomic weight of hydrogen is such an odd number as 1.008, then something must be lost out somehow when the elements are built up out of hydrogen atoms. What is lost is, after all, just the 0.008 of the 1.008, which is thus converted into 1.000. This explains why four hydrogen atoms packed into helium weigh only 4, or sixteen in oxygen only 16. Thus chemists have their desire fulfilled, and all of the atomic weights other than that of hydrogen are whole numbers. Since the publication of Professor Harkins's whole-number rule it has been amply verified, for it has been proved by experiment that if only one kind of chlorine is taken, the atomic weight comes out just a whole number.

The importance of this may be brought out if we take a concrete case of such a size that we can grasp it. Let us suppose we are able to transmute hydrogen into oxygen on a large scale, although we are not yet able to do it even on a small scale. Let us fill a large glass flask with pure hydrogen. We will weigh into the

flask sixteen and one-eighth ounces of hydrogen and seal up the flask so that nothing can escape. Then we will set the reaction going; no matter how, for we do not know how. It would give a tremendous amount of heat and doubtless burst the flask or melt it, but we need not mind such little difficulties in an imaginary experiment. When all the hydrogen has been changed over into oxygen we will weigh the flask again and will find that its contents now weigh an even pound! What has become of the extra eighth of an ounce? The flask, we will assume, is tight. Nothing has got out of it but light and heat, which are not matter but energy, mere waves in the ether—if there is an ether.

It seems, then, that matter may be transmuted into energy and the reverse. If so, we shall have to combine the two laws of the conservation of mass and energy into one, since neither seems able to stand alone. This new view does not invalidate any of the old knowledge but brings us nearer to that unity of conception that is the aim of science. It is not a denial of matter any more than it is a denial of energy but enables us to understand better what they really are and how they are related. It explains many things that have puzzled us possibly more than that old problem of where the sun gets its heat. For the youngest stars consist mostly of hydrogen and the gas that is next to it in lightness, helium. The older stars that are cooling down like our sun contain heavier elements, like carbon and iron. Now, if these are formed from hydrogen in the process of cooling down, they must have enough heat to radiate for many million years.

On the other hand we have additional direct evidence in support of Prout's hypothesis that the elements are made out of hydrogen, for hydrogen has been got out of some of them. Sir Ernest Rutherford has found that he can get traces of hydrogen by bombarding another gas, such as nitrogen, with the swift and minute projections that are shot out from the radium atom. This upsets another old notion, that no element could be broken into other elements.

EDWIN E. SLOSSON, *Chats on Science* (The Century Co.), p. 66.

10. The Pigmentary Effector System

No biological discovery of recent years has been more fruitful in throwing light on dark places than has the discovery of the endocrine glands and the effects of their secretions. It has cleared up a great many points in the working of the adult animal machine,

and also in the mode of its development, which previously had baffled research. As an example of the former, we may take the facts concerning adrenalin, one of the secretions of the adrenal glands. This is usually released into the blood-stream at a constant and slow rate; but in case of emergency can be poured in quickly, and then appears to tune up the body in a particular way, making it ready to meet danger of struggle by violent action, by stimulating and sensitizing certain organs, while others are kept at subnormal level of activity. As an example of the second, we have the metamorphosis of animals such as the frog. How is it that all the complicated processes therein involved, the growth of limbs and skeleton, the loss of gills and tail, the change in the skin, etc., can all be synchronized so that all occur together at the right moment? The answer is this—that all the various tissues and organs involved are sensitive to the action of the thyroid's secretion, and that the process of metamorphosis is brought about when a certain concentration of the secretion has been reached in the circulation.

Dr. Hogben[1] has for some years been interesting himself in another puzzling problem—the problem of colour-change in animals. As often in physiology, the frog has proved an admirable *corps vile* for experiment. As most people know, the frog is capable of great changes in colour and shade, from a brown which is almost black through brown-green to greenish-yellow. As a result of his work Dr. Hogben has clearly established that this colour change is brought about chiefly through the action of one of the secretions of the pituitary gland, at the base of the brain. This secretion acts upon the pigment cells in the skin, causing their contained pigment to spread through their branching arms, or to become condensed in a minute dot at the centre; in the former case the animal looks dark, in the latter light.

The capacity of the frog to change colour according to the surroundings in which it is placed seems to depend upon the following sequence of events. The nerve-paths in the brain are so constructed that changes in the eye can affect the pituitary; and thus dark or light backgrounds can change the pituitary's activity, and cause it to secrete more or less than normal; and this in its turn will cause a greater or less expansion of the pigment cells and a difference in the frog's appearance. There are numerous minor de-

[1] LANCELOT, T., *The Pigmentary Effector System*, HOGBEN, D.Sc., No. 1 of Biological Monographs and Manuals, edited by F. A. E. Crew and D. W. Cutler (Oliver & Boyd, Edinburgh, 1924).

tails and qualifications into which there is here no space to enter, but the pituitary is the kernel of the problem.

Before the principle of internal secretion was recognized, reactions of animals to their surroundings were naturally first thought of in terms of nervous control—the only form of control then known which appeared adequate. The earlier history of research on the problem of colour-change in the frog is extremely instructive in this respect. Worker after worker set out with the conviction that it was all a matter of nervous control, that messages were sent direct to the individual pigment cells by individual nerve fibres from the brain or spinal cord; and what is more, they generally succeeded in finding evidence to support their view. Unfortunately, however, the evidence of different workers was entirely contradictory! Dr. Hogben gives reasons for much of this contradiction, showing how tampering with the nervous system might interfere directly with the pituitary, or might modify its effects by interfering with the circulation, etc. The whole history, as set forth here, is a most instructive example of how the average man can only find what he sets out to find, and of the extreme value of general ideas to the progress of science.

When we turn to other forms, we find that colour response need not always be effected in the same way as in the frog. In reptiles, for example, the evidence so far as it goes suggests that the adrenal secretion is the chief agent in controlling the pigment cells, while in fishes they are certainly under the direct control of the nervous system (although probably this control is abetted by internal secretions). Finally, in birds and mammals, although, of course, pigmented cells exist, no response of these to either internal secretion or nervous control occurs.

These facts illustrate certain important principles which are not always appreciated either by biologists or laymen. In the first place, hasty speculation, as revealed in the numerous semi-popular books on "glands" and also too often in medical and biological literature, is prone to assume that the effects of a gland and its secretion must always be the same wherever they are found to occur. This is not only unjustified, but incorrect. If it takes two to make a quarrel, so it takes two to make an endocrine effect—first the secretion of the gland in question, and then the power of some of the tissues of the body to respond to that secretion. Tissues which in one animal respond to thyroid, in another animal do not. For

instance, in frog or toad tadpoles, thyroid causes the limbs to grow, the tail to disappear. In newt or salamander tadpoles, on the other hand, neither of these effects occur; although in both kinds of animals the gills, the skeleton and the brain are sensitive to the thyroid's action.

Even in one and the same animal at different periods of its career the same holds good. Once the frog tadpole has become a frog, its limbs no longer can respond to thyroid secretion.

This leads on to a rather different conception of the endocrine glands from the one which we might be tempted to adopt instinctively. There is gradually accumulating a great body of evidence which suggests that the bulk at least of the glands of internal secretion produce the same substance, or at least very closely allied substances, throughout the whole vertebrate series. Pituitary secretion from any vertebrate will cause the expansion of the frog's pigment cells as readily as the secretion of its own pituitary—even pituitary secretion from an animal like a fowl or a rabbit in which the pituitary is powerless to effect colour change. In the same way, thyroid from any animal will accelerate the metamorphosis of tadpoles—even from animals like sheep in which there is no metamorphosis, or from creatures like Necturus in which no effects of the thyroid on growth or differentiation have yet been shown to exist at all.

Insulin and adrenalin are produced by all vertebrates too, and it is probable that other secretions are also similar or identical throughout the series.

In other words, the glands of internal secretion constitute what we may call a chemical ground-plan for the vertebrates, a ground-plan equally constant throughout the whole group as is the ground-plan of their structure as set forth in any textbook of comparative anatomy.

But the structural ground-plan may be modified in all sorts of ways to fit its possessor for different modes of life. The same plan is to be found in the fore-limbs of a whale, a man, a horse, a bird, a bat, a frog, a lion, although each subserves a wholly different function. So with the chemical plan. By varying the response capacities of the various tissues, the same internal secretions can be made to perform wholly different functions in the life of different kinds of animals. Here, it seems to me, is a new principle of great general importance which has emerged as a result of the exten-

sion of research on the internal secretions from man and mammals to lower vertebrates.

JULIAN HUXLEY in *Discovery*, Vol. VI, p. 8.

11. A New Method of Measuring Star Distances

There are in the heavens hundreds of variable stars known as *Cepheids*. In studying them it has been found that there is a close relation between the total light power and the interval of time between successive productions of light. This gives a clue for a new method of measuring the distance of these stars—lying far beyond the range of the old triangulation or parallax method. Professor Harlow Shapley of the Harvard Observatory thus explains the method:

If, for a variable star, the period between successive oscillations of brightness is twelve hours, the star is found to be about one hundred times as luminous as the sun; if its period is twelve days, the brightness excels that of the sun two thousandfold. The relation between period and candle-power is so definite that, wherever the variable may be, a study of its periodic variations in light yields readily the absolute value of its luminosity, and from that value a simple computation leads to the distance. In other words, knowing from its period of variability the actual light power of a star, the measure of its apparent brightness indicates the distance from the observer. This method of measuring space is called photometric, in distinction from the trigonometric method used for nearer stars, planets, and comets. Fortunately for the problem of measuring the Milky Way, the Cepheid variables are widely distributed; they appear among the bright and faint stars of the Galaxy, as well as in the crowded population of remote star-clusters and clouds.

The photometric method, we are told, can be applied also to the study of light from blue-tinted stars located in distant globular clusters, in comparison with relatively near-by stars of the same hue; interstellar space being so nearly empty that even the shorter rays of the spectrum are not scattered in passing through distances measured in thousands of light-years. In the familiar globular cluster in Hercules, Messier 13, there are also found two Cepheid variables; and distance-estimates based on the study of these agree with those from study of the blue stars in the same cluster. Cepheid variables appear in other globular clusters, but their periods have not always been determined; and there are many globular clusters

that lack Cepheids—though containing twenty or thirty thousand stars brighter than the sun. As to the measurement of the distance of these, and the corroboration given in case of the most distant of them all by evidence supplied by the world's largest telescope, we read:

By assuming, for instance, that all globular clusters actually have the same size and absolute brightness (an assumption that has been found to be justified) we can compute distances from measures of angular size and apparent brightness, and thus be independent of Cepheid variables. Using these indirect methods it was eventually possible, a few years ago, to get the distances of all known globular clusters. It then appeared that the Hercules system is one of the nearest. The most remote so far on record is N. G. C. 7006, which probably does not differ materially from the cluster in Hercules, but because of its great distance appears to us as diminutive and very faint. Its angular diameter is so small that only the largest telescope can distinguish it from a single hazy-star, or from a nebula. With the 100-inch reflector at Mount Wilson, Cepheid variables have been found within this distant object, and the analysis of their magnitudes has checked and proved correct the values of distance we had previously derived from comparing its angular diameter and apparent magnitude with the same properties for near-by clusters of known distance.

It is interesting to reflect that when we study the periods of Cepheids in N. G. C. 7006 we are photographing and analyzing waves or pulses of light that were emitted from the hot stellar atmospheres more than two thousand centuries ago. But the radiation, after its long interval in space, shows no measurable effects. It is identical, in natural properties, with the radiation from the sun that has had an experience of only five hundred seconds with the rigors of space and time.

Considered as a whole, the globular clusters form a system of higher order—an organization that is equally divided by the galactic plane, and is about three hundred thousand light-years in greatest diameter. We can, for the present at least, take this organization of clusters as coincident with the general galactic system. Most of the thousands of millions of stars of the Milky Way are confined to a relatively thin and extensive segment—five or ten thousand light-years in thickness and two or three hundred thousand light-years in greatest diameter.

Such, then, is our universe as present-day astronomy conceives

it. In Professor Shapley's concluding words "its stars are now numbered by the thousands of millions, its dimensions measured in hundreds of thousands of light-years, and the probable past duration in time is inexpressible in its immensity."

From the *Literary Digest*, June 13, 1925, p. 22.

12. The Largest Object Known to Science

What is described as a cloud of galaxies, containing more than a hundred spiral nebulæ, each similar in nature to the group of stars of which the sun and all the visible stars are part, is the object under study at the Harvard Observatory by Dr. Harlow Shapley, director of the observatory, and Miss Adelaide Ames, of the observatory staff.

So distant is this cloud of nebulæ that the light from the center of it takes about ten million years to reach the earth, though traveling fast enough to go from New York to California in a seventy-fifth of a second. Its diameter is approximately one-fifth of its distance from the sun, says Dr. Shapley, so that a beam of light would take about two million years to cross it. Thus it is the largest thing known to science, and the most distant that has been measured.

The cluster is located in the neighboring constellations of Virgo and Coma Berenices, or Berenice's Hair, and includes at least 103 well defined spiral nebulæ. One of these is known as Messier 61, and in it two German astronomers recently discovered a nova, or new star, which flashed out from previous obscurity. The brightness of this nova was so much fainter than such novæ which occur in the sun's neighborhood that it confirmed the distance of ten million light-years estimated by Dr. Shapley to be the distance of the cluster.

That these nebulæ actually belong to one system is indicated by their concentration as compared with regions of the sky nearby where the nebulæ are much scarcer. Of the 103 in the group, says Dr. Shapley, two-thirds are within five degrees, or ten times the diameter of the moon, of the center, while thirty-seven are within three degrees of the center.

That the spiral nebulæ, of which many thousands are known in various parts of the sky, are stellar systems or galaxies outside the system of which the sun is a member, was shown last year by Dr. Edwin P. Hubble, of the Mount Wilson Observatory, who measured

the distance of two of the most conspicuous of them. These two were both shown to be about a million light-years away, and while they are considerably smaller than our galaxy, including the Milky Way, they are very similar to it. Dr. W. W. Campbell, president of the University of California and director of the Lick Observatory, one of America's most eminent astronomers, is an address before the American Astronomical Society, following the announcement of Dr. Hubble's work, said: "We do not know, I must confess, that our stellar system is now a spiral nebula, or that it is the developed product of a spiral of ages past, but it does seem to have most of the known attributes of a spiral."

Boston Transcript, July 31, 1926.

13. The Smallest Object Known to Science

Dealing with the nature of matter, which has baffled mankind since the beginning of time, Dr. Willis R. Whitney, Director of the Research Laboratory of the General Electric Company, made new generalizations from the work of J. J. Thomson and R. A. Millikan, saying:

Matter is at least not merely dry and hard, nor yet soft and wet. It is electronic and celestial, whatever that may mean, and the most we know about it is that it is almost entirely space. It is as empty as the sky. It is almost as empty as a perfect vacuum, although it usually contains a lot of energy.

For example, a vacuum through which light is passing contains radiant energy. Apparently matter is only this same vacuum in which there are enormous numbers of positive and negative electric charges, which, however, occupy or fill only an exceedingly small portion of the space attributed to matter.

Novel, simplifying generalizations are interesting, but dangerous, for, as some one has said, no generalization in nature is strictly true, not even this one. Nowadays we say that every gram of all matter consists of 600,000 billion billions—600,000,000,000,000,000,000,000—electrons and an equal quantity of positive electricity. Then we immediately start drawing conclusions.

Atoms of all the elements, from the smallest to the largest, including the isotopes, can be constructed by orderly assemblies of positive and negative electric charges. A slight correction in the case of hydrogen interests the physicist, but need not interfere with our simple picture. (For a discussion of this correction see above, p. 276.)

Atoms begin to look like solar and planetary systems with differ-

ent groups of positive and negative charges at their centers, constituting a sort of sun or nucleus. This nucleus varies in charge or mass from element to element.

Around this center group are the concentric systems of electrons and the outermost groups of these determine most of the characteristic properties. For example, the hydrogen atom is one positive and one negative electron in an orbit around it. This outfit, or atom, is not quite inconceivably small.

It may be worth while to picture it, because the other elements are compounds of the same elementary components. Possibly the dimensions given are still merely the outer dimensions of more empty space. Physicists have shot small projections through matter, so that we are convinced of its highly open-work structure. The projectiles were helium nuclei and electrons.

The actual smallness of an atom is impossible to realize, but so much seems known about its dimensions that we must accept it and try to apply it.

A molecule of water contains two atoms of hydrogen. Suppose we start with one single drop of water and let all of its hydrogen atoms appear in turn as drops of water. How much of a rainfall must we picture in order to visualize all those hydrogen atoms of that drop? We know that the drop contains about 3×10^{21} hydrogen atoms. If these were as large as raindrops they could cover the whole world with a foot of water.

Another way of expressing the raindrops which correspond in number to the hydrogen atoms in a drop of water is to say that if they fell as rapidly as in the heaviest rainfall, this rain would have to continue all over the United States for nearly two weeks.

Now, if we made one of these hydrogen atoms, which we used to think of as hard and indivisible, so large that it became a yard in diameter, nothing would yet become appreciable to the audience, because its electron would still be only a pinhead in size, and its nucleus two thousand times smaller. So while you might distinguish the orbit, its planet and sun would still be invisible.

In other words, practically all of our first atom is apparently space. Between the two charges there is an electrical force holding them in position just as gravity holds the four moons of Jupiter about that planet, for example.

Dr. Whitney described the composition of matter as the chemist now sees it, and demonstrated by experiments the realities of these unimaginably small particles. He showed their relationship to

X-rays. He made them audible by means of a radio loud-speaker, and permitted his hearers to listen for a few moments to the disintegration of the atoms of a piece of uranium, which behaves in a similar manner to radium.

From the *Literary Digest*, September 12, 1925, p. 74.

Note: The student should compare Dr. Whitney's account with the two examples above, pages 146 and 213.

14. Ahikar and Æsop: Literary Coincidences

In *Discovery*, Vol. V, No. 54, June 1924, I briefly described the character of the Aramaic papyri which were discovered at Elephantine and the interesting light which the documents throw upon the life of a Jewish community in Egypt in the fifth century B.C. I there mentioned, but reserved for future discussion, the most important of the literary texts, a sadly fragmentary but apparently authentic version of *The Words of Ahikar*. The importance of this document, and the nature of the problems which it raises, I will now attempt briefly to indicate.

Of the *Story of Ahikar* a number of versions in different languages have for some time been an object of study. The book falls into four sections. (1) The aged and childless Ahikar, who is vizier to Sennacherib, adopts his nephew and obtains the assent of his royal master to lay down the burden of office and put his nephew in his place. (2) The old man instructs the young successor and prepares him for his responsibilities by reciting a series of wise saws and proverbial sayings. (3) The nephew proves ungrateful and treacherous and succeeds in persuading the king that Ahikar is plotting against him. Ahikar is condemned to death, but is secretly saved by his executioner to whom he had shown kindness in the day of his prosperity. Some time afterwards the king of Egypt sends an ultimatum to Sennacherib propounding a series of riddles which must be answered under threat of war. The king laments the loss of Ahikar's wisdom in this emergency; the kindly executioner reveals that the sage is still, in fact, alive; the old man is released from his captivity, triumphantly outwits the enemy and is restored to favour. (4) The whole story of the nephew's treachery is revealed and the villain is handed over to Ahikar for punishment. The wronged sage delivers himself of a series of maxims and fables which are directed to the topic of the righteous nemesis which ultimately attends wrongdoing. After listening to this recital the vil-

lain incontinently swells up and bursts asunder. Thus sections (1) and (3) form the story, which serves as a frame to (2) maxims of worldly wisdom and (4) fables to illustrate the wages of ingratitude and sin.

The new version, upon the whole, triumphantly vindicates tradition, particularly as regards the story frame. It has, it is true, some rather disturbing variations. Thus section (2) is entirely omitted and section (4), so far as one can be certain from its very fragmentary condition, appears to be a jumble of both kinds of maxim. Bold though the supposition may be, I am myself inclined to believe that our particular copy represents a degenerate version. In the analysis of books of this kind, literary forms which have become stereotyped are highly important clues. Now the combination of (1) and (2), independently of the Ahikar sequel, is a fixed form in Egyptian gnomic literature, to which, indeed, the oldest extant literary document, *The Proverbs of Ptah-hotep*, conforms. I am therefore inclined to believe that it is a rather an accidental dislocation in the particular copy, and not an essential difference in the prototype which has caused the omission of (2) in the Aramaic.

The fragmentary state of the papyrus gives us no certain indication whether the riddles were in the Aramaic or not. I have little doubt that they were. This is not only a familiar folktale *motif* but further parallels can be quoted from earlier Egyptian literature.

Before the discovery of the Aramaic papyrus the earliest fixed date for the circulation of the *Story of Ahikar* was provided by two references in the *Book of Tobit*. It was then a matter of dispute among scholars as to whether our romance had been composed by a Jew or by a Greek, but it was very generally believed that, wherever it was put together, it was a relatively late compilation of the Hellenistic period. It is true that Clement of Alexandria stated that the Greek philosopher Democritus (born about 460 B.C.) was said to have translated the *Story of Ahikar* from a Babylonian monument, but this was discounted by the knowledge that the manufacture of apocryphal works and their ascription to well-known authors was not at all uncommon in Hellenistic times.

Yet that an Ahikar written in Greek and ascribed to Democritus was once in circulation was not denied, for Clement is here confirmed in rather a curious way. In *The Book of Religions and Sects* by Sharastani, who lived A.D. 1071-1153, several sayings of Democritus are quoted, which can with certainty be identified with pas-

sages in the *Book of Ahikar*. A more doubtful identification shows, if it is sound, that the Democritean Ahikar was in circulation in the time of Plutarch, i.e., in the second century A.D. But it was argued that since the book itself was a Hellenistic forgery, a Greek version of it could obviously not have been made by Democritus.

It is evident that the discovery of the Aramaic text has altered the whole aspect of the problem. Clearly if the Jews of Elephantine were reading a copy of the book in the fifth century B.C., *Ahikar* cannot have been first invented two or three centuries later. It is true that some scholars still maintain that though *Ahikar* may be older, the Greek Ahikar is still to be regarded as a pseudo-Democritean forgery of the third century B.C. But if we put aside the prejudices which inevitably appear when old views have to be adjusted to a new piece of evidence, there is surely no *a priori* reason, now that we know the romance to have been in popular circulation in the fifth century B.C., why tradition may not be right and Democritus may not have really translated a Babylonian original into Greek. In general, I am personally of the opinion that Professor Burnet has taught us to be over-sceptical as to the extent of the debt of Ionian science to the East. In passing, two small points may be noticed. They cannot be said to prove anything, but they are, nevertheless, interesting. Democritus was said to have used a Babylonian source. Upon linguistic grounds the best opinion seems to regard the papyrus version as derived not from a Jewish but from a Mesopotamian original. Secondly, it is obvious that Democritus did not copy this long story from a pillar (*stete*), but it is interesting to put beside this allegation the discussion by Eduard Meyer of the "I romance" as he calls it, i.e., a narrative cast into the form of autobiography, of which *Ahikar* is a specimen. Meyer points out that this literary form is, in fact, very ancient and bears a direct relation to the monuments of royal and distinguished personages in Egypt and the Ancient East upon which the great deeds of the hero are regularly narrated in the form of a personal statement.

But what general interest, it may be asked, can there be in the question whether or not Democritus wrote a translation which has certainly been lost? To me the chief interest is that in this question the problems of Æsop and even the relation of eastern and western fables are involved. For there are coincidences between section (3) of Ahikar and the *Life of Æsop* and between some of the fables in section (4) and Æsop's *Fables*.

Now, in attempting to trace the priority of the invention of popular stories, for obvious reasons the only fixed dates from which we can work are those provided by literature. These dates, however, are not absolutely reliable. For instance, the earliest literary version of the *Beth-Gelert*-type of story is in the Greek writer Pausanias of the second century after Christ. This does not prove that the story was invented in the west and passed into the eastern literature of Buddhism from Pausanias, because the earliest eastern version, which we happen to possess, may be derived from a succession of antecedent writings which have been lost, and these again may have rested upon a long oral tradition. Nevertheless, dates in literature provide us with the only fixed points which we have to work from. Actually the earliest text of the *Jatakas* or birth stories of Buddha is as late as the fifth century after Christ. Certain sculptures, however, show that some of the stories were stereotyped in substantially the same form two hundred years earlier. It is further argued that the practice of illustrating ethical precepts by means of anecdotes which purport to narrate experiences of the Buddha during his previous incarnations as an animal, is so organic a characteristic of Buddhistic teaching that it probably goes back to Buddha himself, i.e., to the fifth century B.C. The suggestion is further that the Buddha adapted to his use a pre-existing popular literary form, just as Our Lord used parables. The remote antiquity of the *Jatakas* in fact rests only upon an hypothesis, though it is a reasonable hypothesis. Upon this again is ultimately based the view, which at present may be said to hold the field, that the type of beast-fable came to Europe from the Far East.

Let us turn for a moment to *Æsop's Fables*. They were very popular in the Greek world in the fifth century B.C., but though Socrates in prison contemplated turning *Æsop's Fables* into verse, the first written collection was made by Demetrius of Phalerum at the end of the fourth century B.C. But this has been lost, and our own *Æsop* rests upon the editions of Phaedrus, first century after Christ, and Babrius, third century after Christ, while the *Life*, in the form in which we have it, is much later still. The *Life*, therefore, can be left out of account. There is some indication that a *Life* was at least in process of formation as early as Herodotus, but where there are similarities between our *Life* and *Ahikar* or other oriental stories, it is quite possible that the borrowing may have taken place at a relatively late date. The same explanation may hold for some of the fables and, it is possible, as Jacobs thought,

that Phaedrus and Babrius, through Alexandria, may have drawn upon oriental storybooks and incorporated some of their contents. But that explanation will not cover all cases. For example, Aristophanes fortunately referred more than once to the fable of *The Eagle and the Dungbeetle,* which is also known to eastern storytellers. Clearly such early coincidences are more difficult to explain by direct contact, for which historicallly there seems but little opportunity. At the same time independent invention is surely unthinkable.

I have mentioned that there are coincidences between *Æsop* and the *Book of Ahikar,* and Smend has noticed several examples where the Æsopic version appears to be a secondary form of that in Ahikar; unfortunately, none of them happen to be among the fragments which alone remain of the fables in the Aramaic papyrus. But luckily, I think it is possible to date one of the Æsopic versions as early as the first collected edition of the *Fables.* In *Ahikar* a plant retorts to an animal which is eating its leaves "Eat away, but when you are dead, my root will be used to tan your hide." In *Æsop* the story has been adapted (and blunted) in order to fit in with a mistaken popular explanation of the Greek sacrificial usage of sacrificing goats to Dionysus the god of wine. Here the vine says, "You may eat me down to the root, but I shall nevertheless put forth fruit to provide the wine when you are sacrificed." Now Leonidas of Tarentum, who flourished about 270 B.C., turned this fable into an epigram. It is reasonable to suppose that he got it from Demetrius of Phalerum's *Æsop.* If so, the *Ahikar* version, of which it is an adaptation, must be yet older. Thus the case for the authenticity of the *Ahikar* of Democritus is strengthened and we have a definite instance of a story from *Ahikar* being transferred into Greek probably at quite an early date.

Now Meyer has reminded us that the Aramaic *Ahikar* is but a fragment of a lost literature, the popular secular literature of the ancient middle east. "If we omit the scanty remains of the religious writings of the Parsees, of the whole literature of the ancient east from the Indus westwards only those fragments of Israelite-Jewish writings, which have found a place in the canon of the Old Testament, have come down to us through literary tradition." If we add a few precious literary papyri to the list, the otherwise complete loss of the secular literature of Egypt and the middle east is a sad fact. May not the real explanation of some of the early literary coincidences between east and west lie here? May not both have

borrowed from this common but now vanished source? The means is provided by the creation of the Persian empire in the sixth century, a cultural unity, the fringes of which touched India on the one hand and Hellenism on the other. Is not this a more probable hypothesis than any which attempts to establish a direct contact? In Egypt Herodotus heard the story of *The Robbers and the King's Treasury;* before him the latest of the writers of the epic cycle, Eugammon (of Cyrene be it noted) has used a version of it. In the east it appears in the *Jatakas* and seems early to have passed with Buddhism from India into China and Tibet. But Egypt I suspect was its home, and from here eventually both east and west acquired it.

This possibility that many coincidences are due to borrowing from a common source and not from each other is, of course, at present a pure guess, but I believe that it is one that it may be fruitful to follow up. It cannot even be said to be probable until a great deal of detailed work upon particular stories has been done. Perhaps a fortunate discovery of some further papyrus may yet confirm or disprove it. But for the present it seems to me as probable as any other solution of the problem, and as such to merit critical examination.

W. R. Halliday, B.A., B.Litt. in *Discovery*, Vol. VII, pp. 124 *f.*

15. A Brief Outline of the Development of the Theory of Relativity

There is something attractive in presenting the evolution of a sequence of ideas in as brief a form as possible, and yet with a completeness sufficient to preserve throughout the continuity of development. We shall endeavour to do this for the Theory of Relativity, and to show that the whole ascent is composed of small, almost self-evident steps of thought.

The entire development starts off from, and is dominated by, the idea of Faraday and Maxwell, according to which all physical processes involve a continuity of action (as opposed to action at a distance), or, in the language of mathematics, they are expressed by partial differential equations. Maxwell succeeded in doing this for electro-magnetic processes in bodies at rest by means of the conception of the magnetic effect of the vacuum-displacement-current, together with the postulate of the identity of the nature of electro-dynamic fields produced by induction, and the electrostatic field.

The extension of electro-dynamics to the case of moving bodies fell to the lot of Maxwell's successors. H. Hertz attempted to solve the problem by ascribing to empty space (the ether) quite similar physical properties to those possessed by ponderable matter; in particular, like ponderable matter, the ether ought to have at every point a definite velocity. As in bodies at rest, electro-magnetic or magneto-electric induction ought to be determined by the rate of change of the electric or magnetic flow respectively, provided that these velocities of alteration are referred to surface elements moving with the body. But the theory of Hertz was opposed to the fundamental experiment of Fizeau on the propagation of light in flowing liquids. The most obvious extension of Maxwell's theory to the case of moving bodies was incompatible with the results of experiment.

At this point, H. A. Lorentz came to the rescue. In view of his unqualified adherence to the atomic theory of matter, Lorentz felt unable to regard the latter as the seat of continuous electro-magnetic fields. He thus conceived of these fields as being conditions of the ether, which was regarded as continuous. Lorentz considered the ether to be intrinsically independent of matter, both from a mechanical and a physical point of view. The ether did not take part in the motions of matter, and a reciprocity between ether and matter could be assumed only in so far as the latter was considered to be the carrier of attached electrical charges. The great value of the theory of Lorentz lay in the fact that the entire electro-dynamics of bodies at rest and of bodies in motion was led back to Maxwell's equations of empty space. Not only did this theory surpass that of Hertz from the point of view of method, but with its aid H. A. Lorentz was also preëminently successful in explaining the experimental facts.

The theory appeared to be unsatisfactory only in *one* point of fundamental importance. It appeared to give preference to one system of co-ordinates of a particular state of motion (at rest relative to the ether) as against all other systems of co-ordinates in motion with respect to this one. In this point the theory seemed to stand in direct opposition to classical mechanics, in which all inertial systems which are in uniform motion with respect to each other are equally justifiable as systems of co-ordinates (Special Principle of Relativity). In this connection, all experience also in the realm of electro-dynamics (in particular Michelson's experiment) supported the idea of the equivalence of all inertial systems, i.e. was in favour of the special principle of relativity.

The Special Theory of Relativity owes its origin to this difficulty, which, because of its fundamental nature, was felt to be intolerable. This theory originated as the answer to the question: Is the special principle of relativity really contradictory to the field equations of Maxwell for empty space? The answer to this question appeared to be in the affirmative. For if those equations are valid with reference to a system of co-ordinates K, and we introduce a new system of co-ordinates K' in conformity with the—to all appearances readily establishable—equations of transformation then Maxwell's

$$\left.\begin{aligned} x' &= x - vt \\ y' &= y \\ z' &= z \\ t' &= t \end{aligned}\right\} \text{(Galileo transformation)}$$

field equations are no longer valid in the new co-ordinates (x', y', z', t'). But appearances are deceptive. A more searching analysis of the physical significance of space and time rendered it evident that the Galileo transformation is founded on arbitrary assumptions, and in particular on the assumption that the statement of simultaneity has a meaning which is independent of the state of motion of the system of co-ordinates used. It was shown that the field equations for *vacuo* satisfy the special principle of relativity, provided we make use of the equations of transformation stated below:

$$\left.\begin{aligned} x' &= \frac{x - vt}{\sqrt{1 - v^2/c^2}} \\ y' &= y \\ z' &= z \\ T' &= \frac{t - vx/c^2}{\sqrt{1 - v^2/c^2}} \end{aligned}\right\} \text{(Lorentz transformation)}$$

In these equations x, y, z represent the co-ordinates measured with measuring-rods which are at rest with reference to the system of co-ordinates, and t represents the time measured with suitably adjusted clocks of identical construction which are in a state of rest.

Now in order that the special principle of relativity may hold, it is necessary that all the equations of physics do not alter their form in the transition from one inertial system to another, when we make use of the Lorentz transformation for the calculation of this change. In the language of mathematics, all systems of equations that express physical laws must be co-variant with respect to

the Lorentz transformation. Thus, from the point of view of method, the special principle of relativity is comparable to Carnot's principle of the impossibility of perpetual motion of the second kind, for, like the latter, it supplies us with a general condition which all natural laws must satisfy. . . .

A. Einstein in *Nature*, Vol. 106, No. 2677, p. 782 (translation by Dr. Robert W. Lawson).

16. Is the Ether Real?

What may prove to be the most important scientific experiment of several years has been reported by Professor Dayton C. Miller of the Case School at Cleveland. This experiment gives great comfort to the opponents of Dr. Einstein. Some of them say—although this is going too far—that the Einstein theory of relativity stands disproved.

Professor Miller repeated the famous Michelson-Morley experiment, an experiment which has stood for twenty years as one of the chief foundation stones of the theory of relativity. When this experiment was first performed, in 1887, it gave one result. Now, in the hands of Professor Miller, it gives the opposite result.

The Michelson-Morley experiment was an attempt to detect the drift of the ether past the earth. No one pretends to know what the ether is. Disciples of Einstein say that it is nothing; that it does not exist except in the imagination of physicists. Other experimenters maintain its reality. They believe that it is a real medium, although an extremely thin and intangible one. It is believed to fill all space and to carry the rays of light; for example, the light from the distant stars.

If this ether is a real medium the earth must be moving through it at a considerable speed. The earth moves around the sun. The solar system is also moving relative to the other stars. There ought to be a strong wind of ether past the earth, just as a wind of air blows past a moving airship. Michelson and Morley set out to detect this wind of ether. They failed.

Now Professor Miller seems to have succeeded. He tried exactly the same experiment, but he tried it in a different place. The original experiment was performed in the basement of a physical laboratory at Cleveland. Professor Miller's recent experiments were performed on the top of a mountain, Mount Wilson in southern California.

This is Professor Miller's explanation of the discrepancy between his results and the earlier ones. The ether is dragged along, he thinks, by the earth. Close to the average surface of the earth this drag is almost complete. Ether and earth move together.

High up on a mountain, above the average surface of the earth, the perfect drag no longer exists. There is more or less drift of the ether relative to the earth. The Mount Wilson results indicate an ether-wind with a velocity of some ten kilometers a second past the apparatus. This is less than the speed of the earth in its orbit, to say nothing of the speed of the whole solar system. On still higher mountains the ether drift presumably would be speedier still.

Does this mean that the Einstein theory faces disapproval and oblivion? Probably not. No one, least of all Professor Einstein, has ever maintained that the theory of relativity is perfect. Professor Miller's new experiment must stand the tests of criticism and repetition. If it survives them it will prove that the ether is real. To this extent the relativity theories will require modification. That does not mean giving them up.

The real strength of the Einstein point of view does not lie in its explanation of the bending of light rays that pass the sun or in any other of the so-called "proofs" of the theory. All these can be explained, if necessary, by other hypotheses. The great asset of the theory is that it has proved extremely fertile in the field of atomic physics. Nearly all of the modern ideas concerning the atom and its relation to light rays and to electricity make more or less use of the theory of relativity. Here is where physicists will miss the Einstein theory if Professor Miller kills it. Here the theory will find its doughtiest defenders.

Forum, Vol. LXXIV, illustrated section, p. xxix.

18. New German Experiments Confirm Einstein Theory

Failure to find any evidence of the motion of the earth through the ether which is supposed to pervade all space, and thus to confirm the recent work of Dr. Dayton C. Miller, at the Mt. Wilson Observatory in California, is announced by Dr. Rudolph Tomaschek, of the University of Heidelberg, in the *Annalen der Physik.*

Dr. Miller, who is professor of physics at the Case School of Applied Science at Cleveland, repeated the Michelson-Morley experiment on Mt. Wilson, 6000 feet above sea level. This experiment measures the difference in the time taken by two beams of light to

travel in two paths at right angles to each other. While a negligible effect was obtained when it was performed at Cleveland, the Mt. Wilson results showed what was apparently a drift through the ether, because the light beam travelling in the direction of the supposed ether drift took longer to return to the starting point than the one going at right angles to it.

Dr. Tomaschek has repeated two other experiments designed to test the ether drift, both of which use a charged condenser, somewhat similar to the condensers used in radio receiving apparatus. In the first one he sought to observe the magnetic field which should be produced by the motion of such a condenser through the ether, but none was observed, even though it was performed at altitudes of 65 feet, 1850 feet and 11,400 feet, the latter being on the Jungfrau, one of the highest peaks in the Alps.

The other experiment was one originally performed in England by Professor F. T. Trouton and H. R. Noble, of the University of London, in 1903. This consisted in suspending a light disc-shaped condenser, also electrically charged, by a fine wire, so that it was free to turn. If the ether is drifting by, the condenser would tend to hang at right angles to the direction of the drift, so the experimenters hung it with its plane in the direction of the supposed motion through the ether, and sought to observe the slight turning of the condenser.

No such turning was observed by the original experimenters, or by Dr. Tomaschek at any of the altitudes, although his apparatus was sufficiently delicate to detect a relative motion of the ether and the earth much smaller than that indicated by Dr. Miller's results. As the Einstein theory of relativity was based partly on the fact that no such ether drift could be observed, and as Professor Miller's work has been said by some authorities to necessitate a considerable modification of the relativity theory, Dr. Tomaschek's work is taken as evidence in its favor.

Daily Science News Bulletin, No. 260B.

APPENDIX I

THE METHODS OF EXPERIMENTAL INQUIRY[1]

By JOHN STUART MILL

1. The simplest and most obvious modes of singling out from among the circumstances which precede or follow a phenomenon, those with which it is really connected by an invariable law, are two in number. One is by comparing together different instances in which the phenomenon occurs. The other is by comparing instances in which the phenomenon does occur, with instances in other respects similar in which it does not. These two methods may be respectively denominated, the Method of Agreement, and the Method of Difference.

In illustrating these methods it will be necessary to bear in mind the two-fold character of inquiries into the laws of phenomena; which may be either inquiries into the cause of a given effect, or into the effects or properties of a given cause. We shall consider the methods in their application to either order of investigation, and shall draw our examples equally from both.

We shall denote antecedents by the large letters of the alphabet, and the consequents corresponding to them by the small. Let *A*, then, be an agent or cause, and let the object of our inquiry be to ascertain what are the effects of this cause. If we can either find, or produce, the agent *A* in such varieties of circumstances, that the different cases have no circumstance in common except *A;* then, whatever effect we find to be produced in all our trials must, it would seem, be the effect of *A*. Suppose, for example, that *A* is tried along with *B* and *C*, and that the effect is *abc;* and suppose that *A* is next tried with *D* and *E*, but without *B* and *C*, and that the effect is *ade*. Then we may reason thus: *b* and *c* are not effects of *A*, for they were not produced by it in the second experiment; nor are *d* and *e*, for they were not produced in the first. Whatever is really the effect of *A* must have been produced in both instances; now this condition is fulfilled by no circumstance except *a*. The phenomenon

[1] From *A System of Logic,* Book III, Chap. viii, Harpers, New York, 1858.

a cannot have been the effect of *B* or *C;* since it was produced where they were not; nor of *D* or *E,* since it was produced where they were not. Therefore it is the effect of *A*.

For example, let the antecedent *A* be the contact of an alkaline substance and an oil. This combination being tried under several varieties of circumstance resembling each other in nothing else, the results agree in the production of a greasy and detersive or saponaceous substance: it is therefore concluded that the combination of an oil and an alkali causes the production of a soap. It is thus we inquire, by the Method of Agreement, into the effect of a given cause.

In a similar manner we may inquire into the cause of a given effect. Let *a* be the effect. Here, as shown in the last chapter, we have only the resource of observation without experiment: we cannot take a phenomenon of which we know not the origin, and try to find its mode of production by producing it; if we succeeded in such a random trial it could only be by accident. But if we can observe *a* in two different combinations, *abc* and *ade;* and if we know, or can discover, that the antecedent circumstances in these cases respectively were *ABC* and *ADE;* we may conclude by a reasoning similar to that in the preceding example, that *A* is the antecedent connected with the consequent *a* by a law of causation. *B* and *C,* we may say, cannot be causes of *a* since on its second occurrence they were not present; nor are *D* and *E,* for they were not present on its first occurrence. *A,* alone of the five circumstances, was found among the antecedents of *a* in both instances.

For example, let the effect *a* be crystalization. We compare instances in which bodies are known to assume crystaline structure, but which have no other point of agreement; and we find them to have one, and as far as we can observe, only one, antecedent in common: the deposition of a solid matter from a liquid state, either a state of fusion or of solution. We conclude, therefore, that the solidification of a substance from a liquid state is an invariable antecedent of its crystalization.

In this example we may go further, and say, it is not only the invariable antecedent but the cause. For in this case we are able, after detecting the antecedent *A,* to produce it artificially, and by finding that *a* follows it, verify the result of our induction. The importance of thus reversing the proof was never more strikingly manifested than when, by keeping a phial of water charged with siliceous particles undisturbed for years, a chemist (I believe Dr. Wollaston) succeeded in obtaining crystals of quartz; and in the equally interesting experiment in which Sir James Hall produced artificial marble, by the cooling of its materials from fusion under immense pressure: two admirable examples of the light which may be thrown upon the

most secret processes of nature by well-contrived interrogation of her.

But if we cannot artificially produce the phenomenon *A*, the conclusion that it is the cause of *a* remains subject to a very considerable doubt. Though an invariable, it may not be the unconditional antecedent of *a*, but may precede it as day precedes night or night day. This uncertainty arises from the impossibility of assuring ourselves that *A* is the only immediate antecedent common to both the instances. If we could be certain of having ascertained all the invariable antecedents, we might be sure that the unconditional invariable antecedent, or cause, must be found somewhere among them. Unfortunately it is hardly ever possible to ascertain all the antecedents, unless the phenomenon is one which we can produce artificially. Even then the difficulty is merely lightened, not removed: men knew how to raise water in pumps long before they adverted to what was really the operating circumstance in the means they employed, namely, the pressure of the atmosphere on the open surface of the water. It is, however, much easier to analyze completely a set of arrangements made by ourselves, than the whole complex mass of the agencies which nature happens to be exerting at the moment when she produces any given phenomenon. We may overlook some of the material circumstances in an experiment with an electrical machine; but we shall, at the worst, be better acquainted with them than those of a thunder-storm.

The mode of discovering and proving laws of nature, which we have now examined, proceeds upon the following axiom: Whatever circumstance can be excluded, without prejudice to the phenomenon or can be absent notwithstanding its presence, is not connected with it in the way of causation. The casual circumstances being thus eliminated, if only one remains, that one is the cause which we are in search of: if more than one, they either are, or contain among them, the cause: and so, *mutatis mutandis*, of the effect. As this method proceeds by comparing different instances to ascertain in what they agree, I have termed it the Method of Agreement: and we may adopt as its regulating principle the following canon:

FIRST CANON

If two or more instances of the phenomenon under investigation have only one circumstance in common, the circumstance in which alone all the instances agree, is the cause (or effect) of the given phenomenon.

Quitting for the present the Method of Agreement, to which we shall almost immediately return, we proceed to a still more potent instrument of the investigation of nature, the Method of Difference.

2. In the Method of Agreement, we endeavored to obtain instances which agreed in the given circumstance but differed in every other: in the present method we require, on the contrary, two instances resembling one another in every other respect, but differing in the presence or absence of the phenomenon we wish to study. If our object be to discover the effects of an agent *A*, we must procure *A* in some set of ascertained circumstances, as *ABC*, and having noted the effects produced, compare them with the effect of the remaining circumstances *BC*, when *A* is absent. If the effect of *ABC* is *abc*, and the effect of *BC* is *bc*, it is evident that the effect of *A* is *a*. So again, if we begin at the other end, and desire to investigate the cause of an effect *a*, we must select an instance, as *abc*, in which the effect occurs, and in which the antecedents, were *ABC*, and we must look out for another instance in which the remaining circumstances, *bc*, occur without *a*. If the antecedents, in that instance, are *BC*, we know that the cause of *a* must be *A;* either *A* alone, or *A* in conjunction with some of the other circumstances present.

It is scarcely necessary to give examples of a logical process to which we owe almost all the inductive conclusions we draw in daily life. When a man is shot through the heart, it is by this method we know that it was the gun-shot which killed him: for he was in the fullness of life immediately before, all circumstances being the same, except the wound.

The axioms which are taken for granted in this method are evidently the following: Whatever antecedent cannot be excluded without preventing the phenomenon, is the cause, or a condition, of that phenomenon; whatever consequent can be excluded, with no other difference in the antecedents than the absence of a particular one, is the effect of that one. Instead of comparing different instances of a phenomenon, to discover in what they agree, this method compares an instance of its occurrence with an instance of its non-occurrence, to discover in what they differ. The canon which is the regulating principle of the Method of Difference may be expressed as follows:

SECOND CANON

If an instance in which the phenomenon under investigation occurs, and an instance in which it does not occur, have every circumstance save one in common, that one occurring only in the former; the circumstance in which alone the two instances differ, is the effect, or cause, or a necessary part of the cause, of the phenomenon.

3. The two methods which we have now stated have many features of resemblance, but there are also many distinctions between them. Both are methods of *elimination*. This term (which is employed in the theory of equations to denote the process by which one after

another of the elements of a question is excluded, and the solution made to depend upon the relation between the remaining elements only) is well suited to express the operation, analogous to this, which has been understood since the time of Bacon to be the foundation of experimental inquiry: namely, the successive exclusion of the various circumstances which are found to accompany a phenomenon in a given instance, in order to ascertain what are those among them which can be absent consistently with the existence of the phenomenon. The Method of Agreement stands on the ground that whatever can be eliminated, is not connected with the phenomenon by any law. The Method of Difference has for its foundation, that whatever cannot be eliminated, is connected with the phenomenon by a law.

Of these methods, that of Difference is more particularly a method of artificial experiment; while that of Agreement is more especially the resource we employ where experimentation is impossible. A few reflections will prove the fact, and point out the reason of it.

It is inherent in the peculiar character of the Method of Difference that the nature of the combination which it requires is much more strictly defined than in the Method of Agreement. The two instances which are to be compared with one another must be exactly similar, in all circumstances except the one which we are attempting to investigate: they must be in the relation of *ABC* and *BC*, or of *abc* and *bc*. It is true that this similarity of circumstances need not extend to such as are already known to be immaterial to the result. And in the case of most phenomena we learn at once, from the most ordinary experience, that most of the coexistent phenomena of the universe may be either present or absent without affecting the given phenomenon; or, if present, are present indifferently when the phenomenon does not happen, and when it does. Still, even limiting the identity which is required between the two instances, *ABC* and *BC*, to such circumstances as are not already known to be indifferent; it is very seldom that nature affords two instances, of which we can be assured that they stand in this precise relation to one another. In the spontaneous operations of nature there is generally such complication and such obscurity, they are mostly either on so overwhelmingly large or on so inaccessibly minute a scale, we are so ignorant of a great part of the facts which really take place, and even those of which we are not ignorant are so multitudinous, and therefore so seldom exactly alike in any two cases, that a spontaneous experiment, of the kind required by the Method of Difference, is commonly not to be found. When, on the contrary, we obtain a phenomenon by an artificial experiment, a pair of instances such as the method requires is obtained almost as a matter of course, provided the process does not last a long time. A

certain state of surrounding circumstances existed before we commenced the experiment: this is *BC*. We then introduce *A;* say, for instance, by merely bringing an object from another part of the room, before there has been time for any change in the other elements. It is, in short (as M. Comte observes), the very nature of an experiment, to introduce into the preëxisting state of circumstances a change perfectly definite. We choose a previous state of things with which we are well acquainted, so that no unforeseen alteration in that state is likely to pass unobserved; and into this we introduce, as rapidly as possible, the phenomenon which we wish to study; so that we in general are entitled to feel complete assurance that the preëxisting state, and the state which we have produced, differ in nothing except in the presence or absence of that phenomenon. If a bird is taken from a cage, and instantly plunged into carbonic acid gas, the experimentalist may be fully assured (at all events after one or two repetitions) that no circumstance capable of causing suffocation had supervened in the interim, except the change from immersion in the atmosphere to immersion in carbonic acid gas. There is one doubt, indeed, which may remain in some cases of this description; the effect may have been produced not by the change, but by the means we employed to produce the change. The possibility, however, of this last supposition generally admits of being conclusively tested by other experiments. It thus appears that in the study of the various kinds of phenomena which we can, by our voluntary agency, modify or control we can in general satisfy the requisitions of the Method of Difference; but that by the spontaneous operations of nature those requisitions are seldom fulfilled.

The reverse of this is the case with the Method of Agreement. We do not here require instances of so special and determinate a kind. Any instances whatever in which nature presents us with a phenomenon, may be examined for the purposes of this method; and if *all* such instances agree in anything, a conclusion of considerable value is already attained. We can seldom, indeed, be sure that this one point of agreement is the only one; but our ignorance does not, as in the Method of Difference, vitiate the conclusion; the certainty of the result, as far as it goes, is not affected. We have ascertained one invariable antecedent or consequent, however many other invariable antecedents or consequents may still remain unascertained. If *ABC, ADE, AFG,* are all equally followed by *a*, then *a* is an invariable consequent of *A*. If *abc, ade, afg,* all number *A* among their antecedents, then *A* is connected as an antecedent, by some invariable law, with *a*. But to determine whether this invariable antecedent is a cause, or this invariable consequent an effect, we must be able, in addition, to produce the one by means

of the other; or, at least, to obtain that which alone constitutes our assurance of having produced anything, namely, an instance in which the effect, *a*, has come into existence, with no other change in the preëxisting circumstances than the addition of *A*. And this, if we can do it, is an application of the Method of Difference, not of the Method of Agreement.

It thus appears to be by the Method of Difference alone that we can ever, in the way of direct experience, arrive with certainty at causes. The Method of Agreement leads only to laws of phenomena, as Mr. Whewell calls them, but which (since laws of causation are also laws of phenomena) I prefer to designate as uniformities in which the question of causation must for the present remain undecided. The Method of Agreement is chiefly to be resorted to, as a means of suggesting applications of the Method of Difference (as in the last example the comparison of *ABC, ADE, AFG,* suggested that A was the antecedent on which to try the experiment whether it could produce *a*); or, as an inferior resource, in case the Method of Difference is impracticable; which, as we before showed, generally arises from the impossibility of artificially producing the phenomena. And hence it is that the Method of Agreement, although applicable in principle to either case, is more emphatically the method of investigation on those subjects where artificial experimentation is impossible; because on those it is, generally, our only resource of a directly inductive nature; while, in the phenomena which we can produce at pleasure, the Method of Difference generally affords a more efficacious process, which will ascertain causes as well as mere laws.

4. Our next remark shall be, that there are many cases in which, although our power of producing the phenomenon is complete, the Method of Difference either cannot be made available at all, or not without a previous employment of the Method of Agreement. This occurs when the agency by which we can produce the phenomenon is not that of one single antecedent, but a combination of antecedents, which we have no power of separating from each other and exhibiting apart. For instance, suppose the subject of inquiry to be the cause of the double refraction of light. We can produce this phenomenon at pleasure, by employing any one of the many substances which are known to refract light in that peculiar manner. But if, taking one of those substances, as Iceland spar for example, we wish to determine on which of the properties of Iceland spar this remarkable phenomenon depends, we can make no use, for that purpose, of the Method of Difference; for we cannot find another substance precisely resembling Iceland spar except in some one property. The only mode, therefore, of prosecuting this inquiry is that afforded by the Method of Agreement; by which, in fact, through a

comparison of all the known substances which had the property of doubly refracting light, it was ascertained that they agree in the single circumstance of being crystaline substances; and although the converse does not hold, although all crystaline substances have not the property of double refraction, it was concluded, with reason, that there is a real connexion between these two properties; that either crystaline structure, or the cause which gives rise to that structure, is one of the conditions of double refraction.

Out of this employment of the Method of Agreement arises a peculiar modification of that method, which is sometimes of great avail in the investigation of nature. In cases similar to the above, in which it is not possible to obtain the precise pair of instances which our second canon requires—instances agreeing in every antecedent except *A*, or in every consequent except *a;* we may yet be able, by a double employment of the Method of Agreement, to discover in what the instances which contain *A* or *a*, differ from those which do not.

If we compare various instances in which *a* occurs, and find that they all have in common the circumstance *A*, and (as far as can be observed) no other circumstance, the Method of Agreement, so far bears testimony to a connexion between *A* and *a*. In order to convert this proof of connexion into proof of causation by the direct Method of Difference, we ought to be able in some one of these instances, as for example *ABC*, to leave out *A*, and observe whether by doing so, *a* is prevented. Now supposing (what is often the case) that we are not able to try this decisive experiment; yet, provided we can by any means discover what would be its result if we *could* try it, the advantage will be the same. Suppose, then, that as we previously examined a variety of instances in which *a* occurred, and found them to agree in containing *A*, so we now observe a variety of instances in which *a* does *not* occur, and find them agree in *not* containing *A;* which establishes, by the Method of Agreement, the same connexion between the absence of *A* and the absence of *a*, which was before established between their presence. As, then, it had been shown that whenever *A* is present *a* is present, so it being now shown that when *A* is taken away *a* is removed along with it, we have by the one proposition *ABC*, *abc*, by the other *BC*, *bc*, the positive and negative instances which the Method of Difference requires. Thus, if it be true that all animals which have a well-developed respiratory system, and therefore aërate the blood perfectly, agree in being warm-blooded, while those whose respiratory system is imperfect do not maintain a temperature much exceeding that of the surrounding medium, we may argue from this two-fold experience, that the change which takes place in the blood by respiration is the cause of animal heat.

This method may be called the indirect Method of Difference or the Joint Method of Agreement and Difference; and consists in a double employment of the Method of Agreement, each proof being independent of the other, and corroborating it. But it is not equivalent to a proof by the direct Method of Difference. For the requisitions of the Method of Difference are not satisfied, unless we can be quite sure either that the instances affirmative of *a* agree in no antecedent whatever but *A*, or that the instances negative of *a* agree in nothing but the negation of *A*. Now if it were possible, which it never is, to have this assurance, we should not need the joint method; for either of the two sets of instances separately would then be sufficient to prove causation. This indirect method, therefore, can only be viewed as a great extension and improvement of the Method of Agreement, but not as participating in the more cogent nature of the Method of Difference. The following may be stated as its canon:—

THIRD CANON

If two or more instances in which the phenomenon occurs have only one circumstance in common, while two or more instances in which it does not occur have nothing in common save the absence of that circumstance; the circumstance in which alone the two sets of instances differ, is the effect, or cause, or a necessary part of the cause, of the phenomenon.

We shall presently show that the Joint Method of Agreement and Difference constitutes, in another respect not yet adverted to, an improvement upon the common Method of Agreement, namely, in being unaffected by a characteristic imperfection of that method, the nature of which still remains to be pointed out. But as we cannot enter into this exposition without introducing a new element of complexity into this long and intricate discussion, I shall postpone it to the next chapter, and shall at once proceed to the statement of two other methods, which mankind possess for exploring the laws of nature by specific observation and experience.

5. The first of these has been aptly denominated the Method of Residues. Its principle is very simple. Subducting from any given phenomenon all the portions which by virtue of preceding inductions, can be assigned to known causes, the remainder will be the effect of the antecedents which had been overlooked, or of which the effect was as yet an unknown quantity.

Suppose, as before, that we have the antecedents *ABC*, followed by the consequents *abc*, and that by previous inductions (founded, we will suppose, upon the Method of Difference) we have ascertained the causes of some of these effects, or the effects of some of these causes, and are by this means apprised that the effect of *A*

is *a*, and that the effect of *B* is *b*. Subtracting the sum of these effects from the total phenomenon, there remains c, which now, without any fresh experiment, we may know to be the effect of *C*. This Method of Residues is in truth a peculiar modification of the Method of Difference. If the instance *ABC*, *abc*, could have been compared with a single instance of *AB*, *ab*, we should have proved *C* to be the cause of *c*, by the common process of the Method of Difference. In the present case, however, instead of a single instance *AB*, we have had to study separately the causes *A* and *B*, and to infer from the effects which they produce separately, what effect they must produce in the case *ABC* where they act together. Of the two instances, therefore, which the Method of Difference requires—the one positive, the other negative—the negative one, or that in which the given phenomenon is absent, is not the direct result of observation and experiment, but has been arrived at by deduction. As one of the forms of the Method of Difference, the Method of Residues partakes of its rigorous certainty, provided the previous inductions, those which gave the effects of *A* and *B*, were obtained by the same infallible method, and provided we are certain that *C* is the only antecedent to which the residual phenomenon *c* can be referred; the only agent of which we had not already calculated and subducted the effect. But as we can never be quite certain of this, the evidence derived from the Method of Residues is not complete, unless we can obtain *C* artificially and try it separately, or unless its agency, when once suggested, can be accounted for, and proved deductively, from known laws.

Even with these reservations, the Method of Residues is one of the most important among our instruments of discovery. Of all the methods of investigating laws of nature, this is the most fertile in unexpected results; often informing us of sequences in which neither the cause nor the effect were sufficiently conspicuous to attract of themselves the attention of observers. The agent *C* may be an obscure circumstance, not likely to have been perceived unless sought for, nor likely to have been sought for until attention had been awakened by the insufficiency of the obvious causes to account for the whole of the effect. And *c* may be so disguised by its intermixture with *a* and *b*, that it would scarcely have presented itself spontaneously as a subject of separate study. Of these uses of the method, we shall presently cite some remarkable examples. The canon of the Method of Residues is as follows:—

FOURTH CANON

Subduct from any phenomenon such part as is known by previous inductions to be the effect of certain antecedents, and the residue of the phenomenon is the effect of the remaining antecedents.

6. There remains a class of laws which it is impracticable to ascertain by any of the three methods which I have attempted to characterize; namely, the laws of those Permanent Causes, or indestructible natural agents, which it is impossible either to exclude or to isolate: which we can neither hinder from being present, nor contrive that they should be present alone. It would appear at first sight that we could by no means separate the effects of these agents from the effects of those other phenomena with which they cannot be prevented from coexisting. In respect, indeed, to most of the permanant causes, no such difficulty exists: since, though we cannot eliminate them as coexisting facts, we can eliminate them as influencing agents, by simply trying our experiment in a local situation beyond the limits of their influence. The pendulum, for example, has its oscillations disturbed by the vicinity of a mountain; we remove the pendulum to a sufficient distance from the mountain, and the disturbance ceases: from these data we can determine by the Method of Difference, the amount of effect really due to the mountain; and beyond a certain distance everything goes on precisely as it would do if the mountain exercised no influence whatever, which, accordingly, we, with sufficient reason, conclude to be the fact.

The difficulty, therefore, in applying the methods already treated of to determine the effects of Permanent Causes, is confined to the cases in which it is impossible for us to get out of the local limits of their influence. The pendulum can be removed from the influence of the mountain, but it cannot be removed from the influence of the earth: we cannot take away the earth from the pendulum, nor the pendulum from the earth, to ascertain whether it would continue to vibrate if the action which the earth exerts upon it were withdrawn. On what evidence, then, do we ascribe its vibrations to the earth's influence? Not on any sanctioned by the Method of Difference; for one of the two instances, the negative instance, is wanting. Nor by the Method of Agreement; for although all pendulums agree in this, that during their oscillations the earth is always present, why may we not as well ascribe the phenomenon to the sun, which is equally a coexistent fact in all the experiments? It is evident that to establish even so simple a fact of causation as this, there was required some method over and above those which we have yet examined.

As another example, let us take the phenomenon heat. Independently of all hypothesis as to the real nature of the agency so called, this fact is certain, that we are unable to exhaust any body of the whole of its heat. It is equally certain that no one ever perceived heat not emanating from a body. Being unable, then, to separate body and heat, we cannot effect such a variation of circumstances as the foregoing three methods required; we cannot as-

certain, by those methods, what portions of the phenomena exhibited by any body are due to the heat contained in it. If we could observe a body with its heat, and the same body entirely divested of heat, the Method of Difference would show the effect due to the heat, apart from that due to the body. If we could observe heat under circumstances agreeing in nothing but heat, and therefore not characterized also by the presence of a body, we could ascertain the effects of heat from an instance of heat with a body and an instance of heat without a body, by the Method of Agreement; or, if we pleased, we could determine by the Method of Difference what effect was due to the body, when the remainder which was due to the heat would be given by the Method of Residues. But we can do none of these things; and without them the application of any of the three methods to the solution of this problem would be illusory. It would be idle, for instance, to attempt to ascertain the effect of heat by subtracting from the phenomena exhibited by a body, all that is due to its other properties; for as we have never been able to observe any bodies without a portion of heat in them, the effect due to that heat may form a part of the very results, which we affect to subtract in order that the effect of heat may be shown by the residue.

If, therefore, there were no other methods of experimental investigation than these three, we should be forever unable to determine the effects due to heat as a cause. But we have still a resource. Though we cannot exclude an antecedent altogether, we may be able to produce, or nature may produce for us, some modification in it. By a modification is here meant, a change in it, not amounting to its total removal. If some modification in the antecedent *A* is always followed by a change in the consequent *a*, the other consequents *b* and *c* remaining the same; or *vice versa*, if every change in *a* is found to have been preceded by some modification in *A*, none being observable in any of the other antecedents; we may safely conclude that *a* is wholly or in part, an effect traceable to *A*, or at least in some way connected with it through causation. For example, in the case of heat, though we cannot expel it altogether from any body, we can modify it in quantity, we can increase or diminish it; and doing so, we find by the various methods of experimentation or observation already treated of, that such increase or diminution of heat is followed by expansion or contraction of the body. In this manner we arrive at the conclusion, otherwise unattainable by us, that one of the effects of heat is to enlarge the dimensions of bodies; or what is the same thing in other words, to widen the distances between their particles.

A change in a thing, not amounting to its total removal, that is, a change which leaves it still the same thing it was, must be a

change either in its quantity, or in some of its relations to other things, of which relations the principal is its position in space. In the previous example, the modification which was produced in the antecedent was an alteration in its quantity. Let us now suppose the question to be, what influence the moon exerts on the surface of the earth. We cannot try an experiment in the absence of the moon, so as to observe what terrestrial phenomena her annihilation would put an end to; but when we find that all the variations in the *position* of the moon are followed by corresponding variations in the time and place of high water, the place being always either on the side of the earth which is nearest to, or on that which is most remote from, the moon, we have ample evidence that the moon is, wholly or partially, the cause which determines the tides. It very commonly happens, as it does in this instance, that the variations of an effect are correspondent, or analogous, to those of its cause; as the moon moves further towards the east, the high water point does the same: but this is not an indispensable condition; as may be seen in the same example, for along with that high water point, there is at the same instant another high water point diametrically opposite to it, and which, therefore, of necessity, moves towards the west as the moon followed by the nearer of the tide waves advances towards the east: and yet both these motions are equally effects of the moon's motion.

That the oscillations of the pendulum are caused by the earth, is proved by similar evidence. Those oscillations take place between equi-distant points on the two sides of a line, which, being perpendicular to the earth, varies with every variation in the earth's position either in space or relatively to the object. Speaking accurately, we only know by the method now characterized, that all terrestrial bodies tend to the earth, and not to some unknown fixed point lying in the same direction. In every twenty-four hours, by the earth's rotation, the line drawn from the body at right angles to the earth coincides successively with all the radii of a circle, and in the course of six months the place of that circle varies by nearly two hundred millions of miles; yet in all these changes of the earth's position, the line in which bodies tend to fall continues to be directed towards it: which proves that terrestrial gravity is directed to the earth, and not, as was once fancied by some, to a fixed point of space.

The Method by which these results were obtained, may be termed the Method of Concomitant Variations: it is regulated by the following canon:—

FIFTH CANON

Whatever phenomenon varies in any manner whenever another phenomenon varies in some particular manner, is either a cause or

an effect of that phenomenon, or is connected with it through some fact of causation.

The last clause is subjoined, because it by no means follows when two phenomena accompany each other in their variations, that the one is cause and the other effect. The same thing may, and indeed must happen, supposing them to be two different effects of a common cause: and by this method alone it would never be possible to ascertain which of the two suppositions is the true one. The only way to solve the doubt would be that which we have so often adverted to, *viz.*, by endeavoring to ascertain whether we can produce the one set of variations by means of the other. In the case of heat, for example, by increasing the temperature of a body we increase its bulk, but by increasing its bulk we do not increase its temperature; on the contrary (as in the rarefaction of air under the receiver of an air-pump), we generally diminish it: therefore heat is not an effect, but a cause of increase of bulk. If we cannot ourselves produce the variations, we must endeavor, though it is an attempt which is seldom successful, to find them produced by nature in some case in which the preëxisting circumstances are perfectly known to us.

It is scarcely necessary to say, that in order to ascertain the uniform concomitance of variations in the effect with variations in the cause, the same precautions must be used as in any other case of the determination of an invariable sequence. We must endeavor to retain all the other antecedents unchanged, while that particular one is subjected to the requisite series of variations; or in other words, that we may be warranted in inferring causation from concomitance of variations, the concomitance itself must be proved by the Method of Difference.

It might at first appear that the Method of Concomitant Variations assumes a new axiom, or law of causation in general, namely, that every modification of the cause is followed by a change in the effect. And it does usually happen that when a phenomenon *A* causes a phenomenon *a*, any variation in the quantity or in the various relations of *A*, is uniformly followed by a variation in the quantity or relations of *a*. To take a familiar instance, that of gravitation. The sun causes a certain tendency to motion in the earth; here we have cause and effect; but that tendency is *towards* the sun, and therefore varies in direction as the sun varies in the relation of position; and moreover the tendency varies in intensity, in a certain numerical ratio to the sun's distance from the earth, that is, according to another relation of the sun. Thus we see that there is not only an invariable connexion between the sun and the earth's gravitation, but that two of the relations of the sun, its position with respect to the earth and its distance from the earth, are invariably connected as antecedents with the quantity and direction of the

earth's gravitation. The cause of the earth's gravitating at all, is simply the sun; but the cause of her gravitating with a given intensity and in a given direction is the existence of the sun in a given direction and at a given distance. It is not strange that a modified cause, which is in truth a different cause, should produce a different effect. But as the cause is only different in its quantity, or in some of its relations, it usually happens that the effect also is only changed in its quantity or its relations.

Although it is for the most part true that a modification of the cause is followed by a modification of the effect, the Method of Concomitant Variations does not, however, presuppose this as an axiom. It only requires the converse proposition; that anything upon whose modifications, modifications of an effect are invariably consequent, must be the cause (or connected with the cause) of that effect; a proposition, the truth of which is evident; for if the thing itself had no influence on the effect, neither could the modifications of the thing have any influence. If the stars have no power over the fortunes of men, it is implied in the same terms, that the conjunctions or oppositions of different stars can have no such power.

Although the most striking applications of the Method of Concomitant Variations take place in the cases in which the Method of Difference, strictly so-called, is impossible, its use is not confined to those cases; it may often usefully follow *after* the Method of Difference, to give additional precision to a solution which that has found. When by the Method of Difference it has first been ascertained that a certain object produces a certain effect, the Method of Concomitant Variations may be usefully called in to determine according to what law the quantity or the different relations of the effect follow those of the cause.

7. The case in which this method admits of the most extensive employment, is that in which the variations of the cause are variations of quantity. Of such variations we may in general affirm with safety, that they will be attended not only with variations, but with similar variations, of the effect: the proposition, that more of the cause is followed by more of the effect, being a corollary from the principle of the Composition of Causes, which, as we have seen, is the general rule of causation; cases of the opposite description, in which causes change their properties on being conjoined with one another, being, on the contrary, special and exceptional. Suppose, then, that when A changes in quantity, a also changes in quantity, and in such a manner that we can trace the numerical relation which the changes of the one bear to such changes of the other as take place within our limits of observation. We may then, with certain precautions, safely conclude that the same numerical relation will hold beyond those limits. If, for instance, we find that when A is

double, *a* is double; that when *A* is treble or quadruple, *a* is treble or quadruple; we may conclude that if *A* were a half or a third, *a* would be a half or a third, and finally, that if *A* were annihilated, *a* would be annihilated, and that *a* is wholly the effect of *A*, or wholly the effect of the same cause with *A*. And so with any other numerical relation according to which *A* and *a* would vanish simultaneously; as for instance if *a* were proportional to the square of *A*. If, on the other hand, *a* is not wholly the effect of *A*, but yet varies when *A* varies, it is probably (to use a mathematical phrase) a function not of *A* alone but of *A* and something else; its changes will be such as would occur if part of it remained constant, or varied on some other principle, and the remainder varied in some numerical relation to the variations of *A*. In that case, when *A* diminishes, *a* will seem to approach not towards zero, but towards some other limit: and when the series of variations is such as to indicate what that limit is, if constant, or the law of its variation if variable, the limit will exactly measure how much of *a* is the effect of some other and independent cause, and the remainder will be the effect of *A* (or of the cause of *A*).

These conclusions, however, must not be drawn without certain precautions. In the first place, the possibility of drawing them at all, manifestly supposes that we are acquainted not only with the variations, but with the absolute quantities, both of *A* and *a*. If we do not know the total quantities, we cannot, of course, determine the real numerical relation according to which those quantities vary. It is therefore an error to conclude, as some have concluded, that because increase of heat expands bodies, that is, increases the distance between their particles, therefore that distance is wholly the effect of heat, and that if we could entirely exhaust the body of its heat, the particles would be in complete contact. This can never be more than a guess, and of the most hazardous sort, not a legitimate induction: for since we neither know how much heat there is in any body, nor what is the real distance between any two particles, we cannot judge whether the contraction of the distance does or does not follow the diminution of the quantity of heat according to such a numerical relation that the two quantities would vanish simultaneously.

In contrast with this let us consider a case in which the absolute quantities are known: the case contemplated in the first law of motion, *viz.*, that all bodies in motion continue to move in a straight line with uniform velocity until acted upon by some new force. This assertion is in open opposition to the first appearances; all terrestrial objects, when in motion, gradually abate their velocity and at last stop; which accordingly the ancients, with their *inductio per enumerationem simplicem*, imagined to be the law. Every moving body, however, encounters various obstacles, as friction, the resistance of

the atmosphere, etc., which we know by daily experience to be causes capable of destroying motion. It was suggested that the whole of the retardation might be owing to these causes. How was this inquired into? If the obstacles could have been removed, the case would have been amenable to the Method of Difference. They could not be removed, they could only be diminished and the case, therefore admitted only of the Method of Concomitant Variations. This accordingly being employed, it was found that every diminution of the obstacles diminished the retardation of the motion: and inasmuch as in this case (unlike the case of heat) the total quantities both of the antecedent and of the consequent were known; it was practicable to estimate, with an approach to accuracy, both the amount of the retardation and the amount of the retarding causes, or resistances, and to judge how near they both were to being exhausted; and it appeared that the effect dwindled as rapidly, and at each step was as far on the road towards annihilation, as the cause was. The simple oscillation of a weight suspended from a fixed point, and moved a little out of the perpendicular, which in ordinary circumstances lasts but a few minutes, was prolonged in Borda's experiments to more than thirty hours, by diminishing as much as possible the friction at the point of suspension, and by making the body oscillate in a space exhausted as nearly as possible of its air. There could therefore be no hesitation in assigning the whole of the retardation of motion to the influence of the obstacles; and since, after subducting this retardation from the total phenomenon, the remainder was an uniform velocity, the result was the proposition known as the first law of motion.

There is also another characteristic uncertainty affecting the inference that the law of variation which the quantities observe within our limits of observation, will hold beyond those limits. There is of course, in the first instance, the possibility that beyond the limits, and in circumstances, therefore of which we have no direct experience, some counteracting cause might develop itself; either a new agent, or a new property of the agents concerned, which lies dormant in the circumstances we are able to observe. This is an element of uncertainty which enters largely into all our predictions of effects; but it is not peculiarly applicable to the Method of Concomitant Variations. The uncertainty, however, of which I am about to speak, is characteristic of that method; especially in the cases in which the extreme limits of our observation are very narrow, in comparison with the possible variations in the quantities of the phenomena. Any one who has the slightest acquaintance with mathematics, is aware that very different laws of variation may produce numerical results which differ but slightly from one another within narrow limits; and it is often only when the absolute amounts of

variation are considerable, that the difference between the results given by one law and by another, becomes appreciable. When, therefore, such variations in the quantity of the antecedents as we have the means of observing, are but small in comparison with the total quantities, there is much danger lest we should mistake the numerical law, and be led quite to miscalculate the variations which would take place beyond the limits; a miscalculation which would vitiate any conclusion respecting the dependence of the effect upon the cause, which could be founded upon those variations. Examples are not wanting of such mistakes. "The formulæ," says Sir John Herschel,[2] "which have been empirically deduced for the elasticity of steam (till very recently), and those for the resistance of fluids, and other similar subjects," when relied on beyond the limits of the observations from which they were deduced, "have almost invariably failed to support the theoretical structures which have been erected on them."

Under this uncertainty, the conclusion we may draw from the concomitant variations of a and A, to the existence of an invariable and exclusive connexion between them, or to the permanency of the same numerical relation between their variations when the quantities are much greater or smaller than those which we have had the means of observing, cannot be considered to rest upon a complete induction. All that in such a case can be regarded as proved on the subject of causation, is that there is some connexion between the two phenomena; that A, or something which can influence A, must be *one* of the causes which collectively determine a. We may, however, feel assured that the relation which we have observed to exist between the variations of A and a, will hold true in all cases which fall between the same extreme limits; that is, wherever the utmost increase or diminution in which the result has been found by observation to coincide with the law, is not exceeded.

The four methods which it has now been attempted to describe, are the only possible modes of experimental inquiry, of direct induction *a posteriori*, as distinguished from deduction; at least I know not, nor am able to conceive, any other. And even of these, the Method of Residues, as we have seen, is not independent of deduction; though, as it requires specific experience in addition, it may, without impropriety, be included among methods of direct observation and experiment.

These then, with such assistance as can be obtained from Deduction, comprise the available resources of the human mind for ascertaining the laws of the succession of phenomena. . . .

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[2] *Discourse on the Study of Natural Philosophy*, p. 179.

APPENDIX II

THE SCIENTIFIC USE OF THE IMAGINATION [1]

By JOHN TYNDALL

Lastly, physical investigation, more than anything besides, helps to teach us the actual value and right use of the Imagination—of that wondrous faculty, which, left to ramble uncontrolled, leads us astray into a wilderness of perplexities and errors, a land of mists and shadows; but which, properly controlled by experience and reflection, becomes the noblest attribute of man; the source of poetic genius, the instrument of discovery in Science, without the aid of which Newton would never have invented fluxions, nor Davy have decomposed the earths and alkalies, nor would Columbus have found another continent.—Address to the Royal Society by its President, Sir Benjamin Brodie, November 30, 1859.

I carried with me to the Alps this year the burden of this evening's work. Save from memory I had no direct aid upon the mountains; but to spur up the emotions, on which so much depends, as well as to nourish indirectly the intellect and will, I took with me four works, comprising two volumes of poetry, Goethe's *Farbenlehre*, and the work on *Logic* recently published by Mr. Alexander Bain. In Goethe, so noble otherwise, I chiefly noticed the self-inflicted hurts of genius, as it broke itself in vain against the philosophy of Newton. Mr. Bain I found, for the most part, learned and practical, shining generally with a dry light, but exhibiting at times a flush of emotional strength, which proved that even logicians share the common fire of humanity. He interested me most when he became the mirror of my own condition. Neither intellectually nor socially is it good for man to be alone, and the sorrows of thought are more patiently borne when we find that they have been experienced by another. From certain passages in his book I could infer that Mr. Bain was no stranger to such sorrows. Speaking for example of the ebb of intellectual force, which we all from time to time experience, Mr. Bain says: "The uncertainty where to look for the next opening of discovery brings the pain of conflict and the debility of indecision." These words have in them the true ring of personal experience. The action

[1] Discourse delivered before the British Association at Liverpool, September 16, 1870. Reprinted from *Fragments of Science*, Vol. II, Chap. viii, D. Appleton and Company, New York, 1898.

of the investigator is periodic. He grapples with a subject of enquiry, wrestles with it, and exhausts, it may be, both himself and it for the time being. He breathes a space, and then renews the struggle in another field. Now this period of halting between two investigations is not always one of pure repose. It is often a period of doubt and discomfort—of gloom and ennui. "The uncertainty where to look for the next opening of discovery brings the pain of conflict and the debility of indecision." It was under such conditions that I had to equip myself for the hour and the ordeal that are now come.

The disciplines of common life are, in great part, exercises in the relations of space, or in the mental grouping of bodies in space; and, by such exercises, the public mind is, to some extent, prepared for the reception of physical conceptions. Assuming this preparation on your part, the wish gradually grew within me to trace, and to enable you to trace, some of the more occult features and operations of Light and Colour. I wished, if possible, to take you beyond the boundary of mere observation, into a region where things are intellectually discerned, and to show you there the hidden mechanism of optical action.

But how are those hidden things to be revealed? Philosophers may be right in affirming that we cannot transcend experience: we can, at all events, carry it a long way from its origin. We can magnify, diminish, qualify, and combine experiences, so as to render them fit for purposes entirely new. In explaining sensible phenomena, we habitually form mental images of the ultra-sensible. There are Tories even in science who regard Imagination as a faculty to be feared and avoided rather than employed. They have observed its action in weak vessels, and are unduly impressed by its disasters. But they might with equal justice point to exploded boilers as an argument against the use of steam. With accurate experiment and observation to work upon, Imagination becomes the architect of physical theory. Newton's passage from a falling apple to a falling moon was an act of the prepared imagination, without which the "laws of Kepler" could not have been traced to their foundations. Out of the facts of chemistry the constructive imagination of Dalton formed the atomic theory. Davy was richly endowed with the imaginative faculty, while with Faraday its exercise was incessant, preceding, accompanying and guiding all his experiments. His strength and fertility as a discoverer is to be referred in great part to the stimulus of his imagination. Scientific men fight shy of the word because of its ultra-scientific connotations; but the fact is that without the exercise of this power, our knowledge of nature would be a mere tabulation of co-existences and sequences. We should still believe in the succession of day and night, of summer and winter; but the

conception of Force would vanish from our universe; causal relations would disappear, and with them that science which is now binding the parts of nature to an organic whole.

I should like to illustrate by a few simple instances the use that scientific men have already made of this power of imagination, and to indicate afterwards some of the further uses that they are likely to make of it. Let us begin with the rudimentary experiences. Observe the falling of heavy rain-drops into a tranquil pond. Each drop as it strikes the water becomes a center of disturbance, from which a series of ring-ripples expand outwards. Gravity and inertia are the agents by which this wave-motion is produced, and a rough experiment will suffice to show that the rate of propagation does not amount to a foot a second. A series of slight mechanical shocks is experienced by a body plunged in the water, as the wavelets reach it in succession. But a finer motion is at the same time set up and propagated. If the head and ears be immersed in the water, as in an experiment of Franklin's, the *tick* of the drop is heard. Now, this sonorous impulse is propagated, not at the rate of a foot, but at the rate of 4700 feet a second. In this case it is not the gravity but the *elasticity* of the water that comes into play. Every liquid particle pushed against its neighbor delivers up its motion with extreme rapidity, and the pulse is propagated as a thrill. The incompressibility of water, as illustrated by the famous Florentine experiment, is a measure of its elasticity; and to the possession of this property, in so high a degree, the rapid transmission of a sound-pulse through water is to be ascribed.

But water, as you know, is not necessary to the conduction of sound; air is its most common vehicle. And you know that when the air possesses the particular density and elasticity corresponding to the temperature of freezing water, the velocity of sound in it is 1,090 feet a second. It is almost exactly one-fourth of the velocity in water; the reason being that though the greater weight of the water tends to diminish the velocity, the enormous molecular elasticity of the liquid far more than atones for the disadvantage due to weight. By various contrivances we can compel the vibrations of the air to declare themselves; we know the length and frequency of the sonorous waves, and we have also obtained great mastery over the various methods by which the air is thrown into vibration. We know the phenomena and laws of vibrating rods, of organ-pipes, strings, membranes, plates, and bells. We can abolish one sound by another. We know the physical meaning of music and noise, of harmony and discord. In short, as regards sound in general, we have a very clear notion of the external physical processes which correspond to our sensations.

In the phenomena of sound, we travel a very little way from down-

right sensible experience. Still the imagination is to some extent exercised. The bodily eye, for example, cannot see the condensations and rarefactions of the waves of sound. We construct them in thought, and we believe as firmly in their existence as in that of the air itself. But now our experience is to be carried into a new region where a new use is to be made of it. Having mastered the cause and mechanism of sound, we desire to know the cause and mechanism of light. We wish to extend our enquiries from the auditory to the optic nerve. There is in the human intellect a power of expansion—I might almost call it a power of creation—which is brought into play by the simple brooding upon facts. The legend of the spirit brooding over chaos may have originated in experience of this power. In the case now before us it has manifested itself by transplanting into space, for the purposes of light, an adequately modified form of the mechanism of sound. We know intimately whereon the velocity of sound depends. When we lessen the density of the aërial medium, and preserve its elasticity constant, we augment the velocity. When we heighten the elasticity, and keep the density constant, we also augment the velocity. A small density, therefore, and a great elasticity, are the two things necessary to rapid propagation. Now light is known to move with the astounding velocity of 186,000 miles a second. How is such a velocity to be obtained? By boldly diffusing in space a medium of the requisite tenuity and elasticity.

Let us make such a medium our starting-point, and, endowing it with one or two other necessary qualities, let us handle it in accordance with strict mechanical laws. Let us then carry our results from the world of theory into the world of sense, and see whether our deductions do not issue in the very phenomena of light which ordinary knowledge and skilled experiment reveal. If in all the multiplied varieties of these phenomena, including those of the most remote and entangled description, this fundamental conception always brings us face to face with the truth; if no contradiction to our deductions from it be found in external nature, but on all sides agreement and verification; if, moreover, as in the case of Conical Refraction and in other cases, it actually forces upon our attention phenomena which no eye had previously seen, and which no mind had previously imagined—such a conception, must, we think, be something more than a mere figment of the scientific fancy. In forming it, that composite and creative power, in which reason and imagination are united, has, we believe, led us into a world not less real than that of the senses, and of which the world of sense itself is the suggestion and, to a great extent, the outcome.

Far be it from me, however, to wish to fix you immovably in this or in any other theoretic conception. With all our belief of it, it will be well to keep the theory of a luminiferous ether plastic and capable

of change. You may, moreover urge that, although the phenomena occur *as if* the medium existed, the absolute demonstration of its existence is still wanting. Far be it from me to deny to this reasoning such validity as it may fairly claim. Let us endeavour by means of analogy to form a fair estimate of its force. You believe that in society you are surrounded by reasonable beings like yourself. You are, perhaps, as firmly convinced of this as of anything. What is your warrant for this conviction? Simply and solely this: your fellow-creatures behave as if they were reasonable; the hypothesis, for it is nothing more, accounts for the facts. To take an eminent example: you believe that our President is a reasonable being. Why? There is no known method of superposition by which any one of us can apply himself intellectually to any other, so as to demonstrate coincidence as regards the possession of reason. If, therefore, you hold our President to be reasonable, it is because he behaves *as if* he were reasonable. As in the case of the ether, beyond the *"as if"* you cannot go. Nay, I should not wonder if a close comparison of the data on which both inferences rest, caused many respectable persons to conclude that the ether had the best of it. [See the two examples above, p. 295 and p. 296.]

This universal medium, this light-ether as it is called, is the vehicle, not the origin, of wave-motion. It receives and transmits, but it does not create. Whence does it derive the motions it conveys? For the most part from luminous bodies. By the motion of a luminous body I do not mean its sensible motion, such as the flicker of a candle, or the shooting out of red prominences from the limb of the sun. I mean an intestine motion of the atoms or molecules of the luminous body. But here a certain reserve is necessary. Many chemists of the present day refuse to speak of atoms and molecules as real things. Their caution leads them to stop short of the clear, sharp, mechanically intelligible atomic theory enunciated by Dalton, or any form of that theory, and to make the doctrine of "multiple proportions" their intellectual bourne. I respect the caution, though I think it is here misplaced. The chemists who recoil from these notions of atoms and molecules accept, without hesitation, the Undulatory Theory of Light. Like you and me they one and all believe in an ether and its light-producing waves. Let us consider what this belief involves. Bring your imaginations once more into play, and figure a series of sound-waves passing through air. Follow them up to their origin, and what do you there find? A definite, tangible, vibrating body. It may be the vocal chords of a human being, it may be an organ-pipe, or it may be a stretched string. Follow in the same manner a train of ether-waves to their source; remembering at the same time that your ether is matter, dense, elastic, and capable of motions subject to, and determined by, mechanical laws. What then do you expect

. . as the sourc series her-waves? Ask your imagination if it will accept a vibrating multiple proportion—a numerical ratio in a state of oscillation? I do not think it will. You cannot crown the edifice with this abstraction. The scientific imagination, which is here authoritative, demands, as the origin and cause of a series of ether-waves, a particle of vibrating matter quite as definite, though it may be excessively minute, as that which gives origin to a musical sound. Such a particle we name an atom or a molecule. I think the intellect, when focussed so as to give definition without penumbral haze, is sure to realize this image at the last.

With the view of preserving thought continuous throughout this discourse, and of preventing either failure of knowledge or of memory, from causing any rent in our picture, I here propose to run rapidly over a bit of ground which is probably familiar to most of you, but which I am anxious to make familiar to you all. The waves generated in the ether by the swinging atoms of luminous bodies are of different lengths and amplitudes. The amplitude is the width of swing of the individual particles of the waves. In water-waves it is the vertical height of the crest above the trough, while the length of the wave is the horizontal distance between two consecutive crests. The aggregate of waves emitted by the sun may be broadly divided into two classes: the one class competent, the other incompetent, to excite vision. But the light-producing waves differ markedly among themselves in size, form, and force. The length of the largest of these waves is about twice that of the smallest, but the amplitude of the largest is probably a hundred times that of the smallest. Now the force or energy of the wave, which expressed with reference to sensation, means the intensity of the light, is proportional to the square of the amplitude. Hence the amplitude being one-hundred-fold, the energy of the largest light-giving waves would be ten-thousand-fold that of the smallest. This is not improbable. I use these figures not with a view to numerical accuracy, but to give you definite ideas of the difference that probably exists, among the light-giving waves. And if we take the whole range of solar radiation into account—its non-visual as well as its visual waves—I think it probable that the force, or energy, of the largest wave is more than a million times that of the smallest.

Turned into their equivalents of sensation, the different light-waves produce different colours. Red, for example, is produced by the largest waves, violet by the smallest, while green is produced by a wave of intermediate length and amplitude. On entering from air into a more highly refracting substance, such as glass or water, or the sulphide of carbon, all the waves are retarded, but the smallest ones most. This furnishes a means of separating the different classes

of waves from each other; in other words, of analysing the light. Sent through a refracting prism, the waves of the sun are turned aside in different degrees from their direct course, the red least, the violet most. They are virtually pulled asunder, and they paint upon a white screen placed to receive them "the solar spectrum." Strictly speaking, the spectrum embraces an infinity of colours; but the limits of language, and of our powers of distinction, cause it to be divided into seven segments: red, orange, yellow, green, blue, indigo, violet. These are the seven primary or prismatic colours. [See above p. 262.]

Separately, or mixed in various proportions, the solar waves yield all the colours observed in nature and employed in art. Collectively, they give us the impression of whiteness. Pure unsifted solar light is white; and, if all the wave-constituents of such light be reduced in the same proportion, the light, though diminished in intensity, will still be white. The whiteness of the snow with the sun shining upon it, is barely tolerable to the eye. The same snow under an overcast firmament is still white. Such a firmament enfeebles the light by reflecting it upwards; and when we stand above a cloud-field—on an Alpine summit, for instance, or on the top of Snowdon—and see, in the proper direction, the sun shining on the clouds below us, they appear dazzlingly white. Ordinary clouds, in fact, divide the solar light impinging on them into two parts—a reflected part and a transmitted part, in each of which the proportions of wave-motion which produce the impression of whiteness are sensibly preserved.

It will be understood that the condition of whiteness would fail if all the waves were diminished *equally*, or by the same absolute quantity. They must be reduced *proportionately*, instead of equally. If by the act of reflection the waves of red light are split into exact halves, then, to preserve the light white, the waves of yellow, orange, green, and blue, must also be split into exact halves. In short, the reduction must take place, not by absolutely equal quantities, but by equal fractional parts. In white light the preponderance, as regards energy, of the larger over the small waves must always be immense. Were the case otherwise, the visual correlative, *blue*, of the smaller waves would have the upper hand in our colour sensations.

Not only are the waves of ether reflected by clouds, by solids, and by liquids, but when they pass from light air to dense, or from dense air to light, a portion of the wave-motion is always reflected. Now our atmosphere changes continually in density from top to bottom. It will help our conceptions if we regard it as made up of a series of thin concentric layers, or shells of air, each shell being of the same density throughout, a small and sudden change of density occurring in passing from shell to shell. Light would be reflected at the limit-

ing surfaces of all these shells, and their action would be practically the same as that of the real atmosphere. And now I would ask your imagination to picture this act of reflection. What must become of the reflected light? The atmospheric layers turn their convex surfaces towards the sun; they are so many convex mirrors of feeble power; and you will immediately perceive that the light regularly reflected from these surfaces cannot reach the earth at all, but is dispersed in space. Light thus reflected cannot, therefore, be the light of the sky.

But, though the sun's light is not reflected in this fashion from the aërial layers to the earth, there is indubitable evidence to show that the light of our firmament is scattered light. Proofs of the most cogent description could be here adduced; but we need only consider that we receive light at the same time from all parts of the hemisphere of heaven. The light of the firmament comes to us across the direction of the solar rays, and even against the direction of the solar rays; and this lateral and opposing rush of wave-motion can only be due to the rebound of the waves from the air itself, or from something suspended in the air. It is also evident that, unlike the action of clouds, the solar light is not reflected by the sky in the proportions which produce white. The sky is blue, which indicates an excess of the shorter waves. In accounting for the colour of the sky, the first question suggested by analogy would undoubtedly be, Is not the air blue? The blueness of the air has, in fact, been given as a solution of the blueness of the sky. But how, if the air be blue, can the light of sunrise and sunset, which travels through vast distances of air, be yellow, orange, or even red? The passage of white solar light through a blue medium could by no possibility redden the light. The hypothesis of a blue air is therefore untenable. In fact the agent, whatever it is, sends us the light of the sky, exercises in so doing a dichroitic action. The light reflected is blue, the light transmitted is orange or red. A marked distinction is thus exhibited between the matter of the sky, and that of an ordinary cloud, which exercises no such dichroitic action.

By the scientific use of the imagination we may hope to penetrate this mystery. The cloud takes no note of size on the part of the waves of ether, but reflects them all alike. It exercises no selective action. Now the cause of this may be that the cloud particles are so large in comparison with the waves of ether, as to reflect them all indifferently. A broad cliff reflects an Atlantic roller as easily as a ripple produced by a sea-bird's wing; and in the presence of large reflecting surfaces, the existing differences of magnitude among the waves of ether may disappear. But supposing the reflecting particles, instead of being very large, to be very small in comparison with the size of the waves. In this case, instead of the whole wave

being fronted and thrown back, a small portion only is shivered off. The great mass of the wave passes over such a particle without reflection. Scatter, then, a handful of such minute foreign particles in our atmosphere, and set imagination to watch their action upon the solar waves. Waves of all sizes impinge upon the particles, and you see at every collision a portion of the impinging wave struck off; all the waves of the spectrum, from the extreme red to the extreme violet, being thus acted upon.

Remembering that the red waves stand to the blue much in the relation of billows to ripples, we have to consider whether those extremely small particles are competent to scatter all the waves in the same proportion. If they be not—and a little reflection will make it clear that they are not—the production of colour must be an incident of the scattering. Largeness is a thing of relation; and the smaller the wave, the greater is the relative size of any particle on which the wave impinges, and the greater also the ratio of the portion scattered to the total wave. A pebble, placed in the way of the ring-ripples produced by heavy raindrops on a tranquil pond, will scatter a larger fraction of each ripple, while the fractional part of a larger wave thrown back by the same pebble might be infinitesimal. Now we have already made it clear to our minds that to preserve the solar light white, its constituent proportions must not be altered; but in the act of division performed by these very small particles the proportions *are* altered; an undue fraction of the smaller waves is scattered by the particles, and, as a consequence in the scattered light, blue will be the predominant colour. The other colours of the spectrum must to some extent, be associated with the blue. They are not absent, but deficient. We ought, in fact, to have them all, but in diminishing proportions, from the violet to the red. [See above, pp. 143 *f.* and 262-266.]

We have here presented a case to the imagination, and assuming the undulatory theory to be a reality, we have, I think, fairly reasoned our way to the conclusion, that were particles, small in comparison to the sizes of the ether waves, sown in our atmosphere, the light scattered by those particles would be exactly such as we observe in our azure skies. When this light is analysed, all the colours of the spectrum are found, and they are found in the proportions indicated by our conclusion. Blue is not the sole, but it is the predominant colour.

Let us now turn our attention to the light which passes unscattered among the particles. How must it be finally affected? By its successive collisions with the particles the white light is more and more robbed of its shorter waves; it therefore loses more and more of its due proportion of blue. The result may be anticipated. The transmitted light, where short distances are involved, will appear yellow-

ish. But as the sun sinks toward the horizon the atmospheric distances increase, and consequently the number of the scattering particles. They abstract in succession the violet, the indigo, the blue, and even disturb the proportions of green. The transmitted light under such circumstances must pass from yellow through orange to red. This also is exactly what we find in nature. Thus, while the reflected light gives us at noon the deep azure of the Alpine skies, the transmitted light gives us at sunset the warm crimson of the Alpine snows. The phenomena certainly occur *as if* our atmosphere were a medium rendered slightly turbid by the mechanical suspension of exceedingly small foreign particles.

Here, as before, we encounter our sceptical *"as if."* It is one of the parasites of science, ever at hand, and ready to plant itself and sprout, if it can, on the weak points of our philosophy. But a strong constitution defies the parasite, and in our case, as we question the phenomena, probability grows like a growing health, until in the end the malady of doubt is completely extirpated. The first question that naturally arises is this: Can small particles be really proved to act in the manner indicated? No doubt of it. Each one of you can submit the question to an experimental test. Water will not dissolve resin, but spirit will dissolve it; when spirit holding resin in solution is dropped into water, the resin immediately separates in solid particles, which render the water milky. The coarseness of this precipitate depends on the quantity of the dissolved resin. You can cause it to separate either in thick clots or in exceedingly fine particles. Professor Brücke has given us the proportions which produce particles particularly suited to our present purpose. One gramme of clean mastic is dissolved in eighty-seven grammes of absolute alcohol, and the transparent solution is allowed to drop into a beaker containing clear water, kept briskly stirred. An exceedingly fine precipitate is thus formed, which declares its presence by its action upon light. Placing a dark surface behind the beaker, and permitting the light to fall into it from the top or front, the medium is seen to be distinctly blue. It is not perhaps so perfect a blue as may be seen on exceptional days among the Alps, but it is a very fair sky-blue. London, and I fear Liverpool, milk makes an approximation to the same colour, through the operation of the same cause; and Helmholtz has irreverently disclosed the fact that the deepest blue eye is simply a turbid medium.

The action of turbid media upon light was illustrated by Goethe, who, though unacquainted with the undulatory theory, was led by his experiments to regard the firmament as an illuminated turbid medium, with the darkness of space behind it. He describes glasses showing a bright yellow by transmitted, and beautiful blue by reflected light. Professor Stokes, who was probably the first to discern

the real nature of the action of small particles on the waves of ether,[2] describes a glass of a similar kind.[3]

Capital specimens of such glass are to be found at Salviati's, in St. James's Street. What artists call "chill" is no doubt an effect of this description. Through the action of minute particles, the browns of a picture often present the appearance of the bloom of a plum. By rubbing the varnish with a silk handkerchief optical continuity is established and the chill disappears. Some years ago I witnessed Mr. Hirst experimenting at Zermatt on the turbid water of the Visp. When kept still for a day or so, the grosser matter sank, but the finer particles remained suspended, and gave a distinctly blue tinge to the water. The blueness of certain Alpine lakes has been shown to be in part due to this cause. Professor Roscoe has noticed several striking cases of a similar kind. In a very remarkable paper the late Principal Forbes showed that steam issuing from the safety-valve of a locomotive, when favourably observed, exhibits at a certain stage of its condensation the colours of the sky. It is blue by reflected light, and orange or red by transmitted light. The same effect, as pointed out by Goethe, is to some extent exhibited by peat-smoke. More than ten years ago, I amused myself by observing, on a calm day at Killarney, the straight smoke columns rising from the cabin-chimneys. It was easy to project the lower portion of a column against a dark pine, and its upper portion against a bright cloud. The smoke in the former case was blue, being seen mainly by reflected light; in the latter case it was reddish, being seen mainly by transmitted light. Such smoke was not in exactly the condition to give us the glow of the Alps, but it was a step in this direction. Brücke's fine precipitate above referred to looks yellowish by transmitted light; but, by duly strengthening the precipitate, you may render the white light of noon as ruby-coloured as the sun, when seen through Liverpool smoke, or upon Alpine horizons. I do not, however, point to the gross smoke arising from coal as an illustration of the action of small particles, because such smoke soon absorbs and destroys the waves of blue, instead of sending them to the eyes of the observer.

These multifarious facts, and numberless others which cannot be referred to, are explained by reference to the single principle, that,

[2] This is inferred from conversation. I am not aware that Professor Stokes has published anything upon the subject.

[3] This glass, by reflected light, had a colour "strongly resembling that of a decoction of horse-chestnut bark." Curiously enough, Goethe refers to this very decoction: "Man nehme einen Streifen frischer Rinde von der Rosskastanie, man stecke denselben in ein Glas Wasser, und in der kürzesten Zeit werden wir das vollkommenste Himmelblau entstehen sehen."—Goethe's *Werke*, B. xxix., p. 24.

where the scattering particles are small in comparison to the ethereal waves, we have in the reflected light a greater proportion of the smaller waves, and in the transmitted light a greater proportion of the larger waves, than existed in the original white light. The consequence, as regards sensation, is that in the one case blue is predominant, and in the other orange or red. Our best microscopes can readily reveal objects not more than 1/50000th of an inch in diameter. This is less than the length of a wave of red light. Indeed a first-rate microscope would enable us to discern objects not exceeding in diameter the length of the smallest waves of the visible spectrum.[4] By the microscope, therefore, we can test our particles. If they be as large as the light-waves they will infallibly be seen; and if they be not so seen it is because they are smaller. Some months ago I placed in the hands of our President a liquid containing Brücke's precipitate. The liquid was a milky blue, and Mr. Huxley applied to it his highest microscopic power. He satisfied me that had particles of even 1/100000th of an inch in diameter existed in the liquid they could not have escaped detection. But no particles were seen. Under the microscope the turbid liquid was not to be distinguished from distilled water.[5]

But we have it in our power to imitate, far more closely than we have hitherto done, the natural conditions of this problem. We can generate, in air, artificial skies, and prove their perfect identity with the natural one, as regards the exhibition of a number of wholly unexpected phenomena. By a continuous process of growth, moreover, we are able to connect sky-matter, if I may use the term, with molecular matter on the one side, and with molar matter, or matter in sensible masses, on the other. In illustration of this, I will take an experiment suggested by some of my own researches, and described by M. Morren of Marseilles at the Exeter meeting of the British Association. Sulphur and oxygen combine to form sulphurous acid gas, two atoms of oxygen and one of sulphur constituting the molecule of sulphurous acid. It has been recently shown that waves of ether issuing from a strong source, such as the sun or the electric light, are competent to shake asunder the atoms of gaseous molecules.[6] A chemist would call this, "decomposition" by light; but it behooves us, who are examining the power and function of the imagination, to keep constantly before us the physical images which

[4] Dallinger and Drysdale have recently measured cilia 1/200000th of an inch in diameter. 1878.

[5] Like Dr. Burdon Sanderson's "pyrogen," the particles of mastic passed, without sensible hindrance, through filtering-paper. By such filtering no freedom from suspended particles is secured. The application of a condensed beam to the filtrate renders this at once evident.

[6] See *New Chemical Reactions Produced by Light,* Vol. I, p. 96.

underlie our terms. Therefore I say, sharply and definitely, that the components of the molecules of sulphurous acid are shaken asunder by the ether-waves. Enclosing sulphurous acid in a suitable vessel, placing it in a dark room, and sending through it a powerful beam of light, we at first see nothing: the vessel containing the gas seems as empty as a vacuum. Soon, however, along the track of the beam a beautiful sky-blue colour is observed, which is due to light scattered by the liberated particles of sulphur. For a time the blue grows more intense; it then becomes whitish; and ends in a more or less perfect white. When the action is continued long enough, the tube is filled with a dense cloud of sulphur particles, which by the application of proper means may be rendered individually visible.[r]

Here, then, our ether-waves untie the bond of chemical affinity, and liberate a body—sulphur—which at ordinary temperatures is a solid, and which therefore soon becomes an object of the senses. We have first of all the free atoms of sulphur, which are incompetent to stir the retina sensibly with scattered light. But these atoms gradually coalesce and form *particles*, which grow larger by continual accretion, until after a minute or two they appear as sky-matter. In this condition they are individually invisible; but collectively they send an amount of wave-motion to the retina, sufficient to produce the firmamental blue. The particles continue, or may be caused to continue, in this condition for a considerable time, during which no microscope can cope with them. But they grow slowly larger, and pass by insensible gradations into the state of *cloud*, when they can no longer elude the armed eye. Thus, without solution of continuity, we start with matter in the atom, and end with matter in the mass; sky-matter being the middle term of the series of transformations.

Instead of sulphurous acid we might choose a dozen other substances, and produce the same effect with all of them. In the case of some—probably in the case of all—it is possible to preserve matter in the firmamental condition for fifteen or twenty minutes under the continual operation of the light. During these fifteen or twenty minutes the particles constantly grow larger, without ever exceeding the size requisite to the production of the celestial blue. Now when two vessels are placed before us, each containing sky-matter, it is possible to state with great distinctness which vessel contains the largest particles. The eye is very sensitive to differences of light, when, as in our experiments, it is placed in comparative darkness, and the wave-motion thrown against the retina is small. The larger

[r] M. Morren was mistaken in supposing that a modicum of sulphurous acid, in the drying tubes, had any share in the production of the "actinic clouds" described by me. A beautiful case of molecular instability in the presence of light is furnished by peroxide of chlorine as proved by Professor Dewar. 1878.

particles declare themselves by the greater whiteness of their scattered light. Call now to mind the observation, or effort at observation, made by our President, when he failed to distinguish the particles of mastic in Brücke's medium, and when you have done this, please follow me. A beam of light is permitted to act upon a certain vapour. In two minutes the azure appears, but at the end of fifteen minutes it has not ceased to be azure. After fifteen minutes its colour, and some other phenomena, pronounce it to be a blue of distinctly smaller particles than those sought for in vain by Mr. Huxley. These particles as already stated, must have been less than 1/100000th of an inch in diameter. And now I want you to consider the following question: Here are particles which have been growing continually for fifteen minutes, and at the end of that time are demonstrably smaller than those which defied the microscope of Mr. Huxley—*What must have been the size of these particles at the beginning of their growth?* What notion can you form of the magnitude of such particles? The distances of stellar space give us simply a bewildering sense of vastness, without leaving any distinct impression on the mind; and the magnitudes with which we have here to do, bewilder us equally in the opposite direction. We are dealing with infinitesimals, compared with which the test objects of the microscope are literally immense. [See the example above, p. 285.]

Small in mass, the vastness in point of number of the particles of our sky may be inferred from the continuity of its light. It is not in broken patches, nor at scattered points, that the heavenly azure is revealed. To the observer on the summit of Mont Blanc, the blue is as uniform and coherent as if it formed the surface of the most close grained solid. A marble dome would not exhibit a stricter continuity. And Mr. Glaisher will inform you, that if our hypothetical shell were lifted to twice the height of Mont Blanc above the earth's surface, we should still have the azure overhead. By day this light quenches the stars; even by moonlight it is able to exclude from vision all stars between the fifth and the eleventh magnitude. It may be likened to a noise, and the feebler stellar radiance to a whisper drowned by the noise.

What is the nature of the particles which shed this light? The celebrated De la Rive ascribes the haze of the Alps in fine weather to floating organic germs. Now the possible existence of germs in such profusion has been held up as an absurdity. It has been affirmed that they would darken the air, and on the assumed impossibility of their existence in the requisite numbers, without invasion of the solar light, an apparently powerful argument has been based by believers in spontaneous generation. Similar arguments have been used by the opponents of the germ theory of epidemic disease, who have triumphantly challenged an appeal to the microscope and the

chemist's balance to decide the question. Such arguments, however, are founded on a defective acquaintance with the powers and properties of matter. Without committing myself in the least to De la Rive's notion, to the doctrine of spontaneous generation, or to the germ theory of disease, I would simply draw attention to the demonstrable fact, that, in the atmosphere, we have particles which defy both the microscope and the balance, which do not darken the air, and which exist, nevertheless, in multitudes sufficient to reduce to insignificance the Israelitish hyperbole regarding the sands upon the sea-shore.

The varying judgments of men on these and other questions may perhaps be, to some extent, accounted for by that doctrine of Relativity which plays so important a part in philosophy. This doctrine affirms that the impressions made upon us by any circumstance, or combination of circumstances, depend upon our previous state. Two travellers upon the same height, the one having ascended to it from the plain, the other having descended to it from a higher elevation, will be differently affected by the scene around them. To the one nature is expanding, to the other it is contracting, and the impressions which have two such different antecedent states are sure to differ. In our scientific judgments the law of relativity may also play an important part. To two men, one educated in the school of the senses, having mainly occupied himself with observation; the other educated in the school of imagination as well, and exercised in the conceptions of atoms and molecules to which we have so frequently referred, a bit of matter, say 1/50000th of an inch in diameter, will present itself differently. The one descends to it from his molar heights, the other climbs to it from his molecular lowlands. To the one it appears small, to the other large. So, also, as regards the appreciation of the most minute forms of life revealed by the microscope. To one of the men these naturally appear conterminous with the ultimate particles of matter; there is but a step from the atom to the organism. The other discerns numberless organic gradations between both. Compared with his atoms, the smallest vibrios and bacteria of the microscopic field are as behemoth and leviathan. The law of relativity may to some extent explain the different attitudes of two such persons with regard to the question of spontaneous generation. An amount of evidence which satisfies the one entirely fails to satisfy the other; and while to the one the last bold defence and startling expansion of the doctrine by Dr. Bastian will appear perfectly conclusive, to the other[8] it will present itself as

[8] When these words were uttered I did not imagine that the chief labour of demolition would fall upon myself. 1878.

merely imposing a labour of demolition on subsequent investigators.

Let me say here that many of our physiological observers appear to form a very inadequate estimate of the distance which separates the microscopic from the molecular limit, and that, as a consequence, they sometimes employ a phraseology calculated to mislead. When, for example, the contents of a cell are described as perfectly homogeneous or as absolutely structureless, because the microscope fails to discover any structure; or when two structures are pronounced to be without difference, because the microscope can discover none, then, I think the microscope begins to play a mischievous part. A little consideration will make it plain that the microscope can have no voice in the question of germ structure. Distilled water is more perfectly homogeneous than any possible organic germ. What is it that causes the liquid to cease contracting at 39° Fahr., and to expand until it freezes? We have here a structural process of which the microscope can take no note, nor is it likely to do so by any conceivable extension of its powers. Place distilled water in the field of an electro-magnet, and bring a microscope to bear upon it. Will any change be observed when the magnet is excited? Absolutely none; and still profound and complex changes have occurred. First of all the particles of water have been rendered diamagnetically polar; and secondly, in virtue of the structure impressed upon it by the magnetic whirl of its molecules, the liquid twists a ray of light in a fashion perfectly determinate both as to quantity and direction.

Have the diamond, the amethyst, and the countless other crystals formed in the laboratories of nature and of man no structure? Assuredly they have; but what can the microscope make of it? Nothing. It cannot be too distinctly borne in mind that between the microscopic limit, and the true molecular limit, there is room for infinite permutations and combinations. It is in this region that the poles of the atoms are arranged, that tendency is given to their powers; so that when these poles and powers have free action, proper stimulus, and a suitable environment, they determine, first the germ, and afterwards the complete organism. This first marshalling of the atoms, on which all subsequent action depends, baffles a keener power than that of the microscope. When duly pondered, the complexity of the problem raises the doubt, not of the power of our instrument, for that is *nil*, but whether we ourselves possess the intellectual elements which will ever enable us to grapple with the ultimate structural energies of nature.[9]

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[9] "In using the expression 'one sort of living substance' I must guard against being supposed to mean that any kind of living protoplasm is homogeneous. Hyaline though it may appear, we are not at present

In more senses than one Mr. Darwin has drawn heavily upon the scientific tolerance of his age. He has drawn heavily upon time in his development of species and he has drawn adventurously upon matter in his theory of pangenesis. According to this theory a germ, already microscopic, is a world of minor germs. Not only is the organism as a whole wrapped up in the germ, but every organ of the organism has there its special seed. This, I say, is an adventurous draft on the power of matter to divide itself and distribute its forces. But, unless we are perfectly sure that he is overstepping the bounds of reason, that he is unwittingly sinning against observed fact or demonstrated law—for a mind like that of Darwin can never sin wittingly against either fact or law—we ought, I think, to be cautious in limiting his intellectual horizon. If there be the least doubt in the matter, it ought to be given in favour of the freedom of such a mind. To it a vast possibility is in itself a dynamic power, though the possibility may never be drawn upon. It gives me pleasure to think that the facts and reasonings of this discourse tend rather towards the justification of Mr. Darwin, than towards his condemnation; for they seem to show the perfect competence of matter and force, as regards divisibility and distribution, to bear the heaviest strain that he has hitherto imposed upon them.

In the case of Mr. Darwin, observation, imagination, and reason combined have run back with wonderful sagacity and success over a certain length of the line of biological succession. Guided by analogy, in his *Origin of Species* he placed at the root of life a primordial germ, from which he conceived the amazing variety of the organisms now upon the earth's surface might be deduced. If this hypothesis were even true, it would not be final. The human mind would infallibly look behind the germ, and however hopeless the attempt, would enquire into the history of its genesis. In this dim twilight of conjecture the searcher welcomes every gleam, and seeks to augment his light by indirect incidences. He studies the methods of nature in the ages and the worlds within his reach, in order to shape the course of speculation in antecedent ages and world. And though the certainty possessed by experimental enquiry is here shut out, we are not left entirely without guidance. From the examination of the solar system, Kant and Laplace came to the conclusion that its various bodies once formed parts of the same undislocated mass; that matter in a nebulous form preceded matter in its present form; that as the ages rolled away, heat was wasted, condensation followed, planets were

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able to assign any limit to its complexity of structure."—Burdon Sanderson, in the *British Medical Journal,* January 16, 1875.

We have here scientific insight, and its correlative caution. In fact, Dr. Sanderson's important researches are a continued illustration of the position laid down above.

detached; and that finally the chief portion of the hot cloud reached, by self-compression, the magnitude and density of our sun. The earth itself offers evidence of a fiery origin; and in our day the hypothesis of Kant and Laplace receives the independent countenance of spectrum analysis, which proves the same substances to be common to the earth and sun.

Accepting some such view of the construction of our system as probable, a desire immediately arises to connect the present life of our planet with the past. We wish to know something of our remotest ancestry. On its first detachment from the central mass, life, as we understand it, could not have been present on the earth. How, then, did it come there? The thing to be encouraged here is a reverent freedom—a freedom preceded by the hard discipline which checks licentiousness in speculation—while the thing to be repressed, both in science and out of it, is dogmatism. And here I am in the hands of the meeting—willing to end, but ready to go on. I have no right to intrude upon you, unasked, the unformed notions which are floating like clouds, or gathering to more solid consistency, in the modern speculative scientific mind. But if you wish me to speak plainly, honestly, and undisputatiously, I am willing to do so. On the present occasion—

You are ordained to call, and I to come.

Well, your answer is given, and I obey your call.

Two or three years ago, in an ancient London College, I listened to a discussion at the end of a lecture by a very remarkable man. Three or four hundred clergymen were present at the lecture. The orator began with the civilization of Egypt in the time of Joseph; pointing out the very perfect organisation of the kingdom, and the possession of chariots, in one of which Joseph rode, as proving a long antecedent period of civilization. He then passed on to the mud of the Nile, its rate of augmentation, its present thickness, and the remains of human handiwork found therein; thence to the rocks which bound the Nile valley, and which teem with organic remains. Thus in his own clear way he caused the idea of the world's age to expand itself definitely before the minds of his audience, and he contrasted this with the age usually assigned to the world. During his discourse he seemed to be swimming against a stream, he manifestly thought that he was opposing a general conviction. He expected resistance in the subsequent discussion; so did I. But it was all a mistake; there was no adverse current, no opposing conviction, no resistance; merely here and there a half-humorous, but unsuccessful attempt to entangle him in his talk. The meeting agreed with all that had been said regarding the antiquity of the earth and of its

life. They had indeed, known it all long ago, and they rallied the lecturer for coming amongst them with so stale a story. It was quite plain that this body of clergymen, who were, I should say, to be ranked amongst the finest samples of their class, had entirely given up the ancient landmarks, and transported the conception of life's origin to an indefinitely distant past.

This leads us to the gist of our present enquiry, which is this: Does life belong to what we call matter or is it an independent principle inserted into matter at some suitable epoch—say when the physical conditions became such as to permit of the development of life? Let us put the question with the reverence due to a faith and culture in which we all were cradled, and which are the undeniable historic antecedents of our present enlightenment. I say, let us put the question reverently, but let us also put it clearly and definitely. There are the strongest grounds for believing that during a certain period of its history the earth was not, nor was fit to be, the theatre of life. Whether this was ever a nebulous period, or merely a molten period, does not signify much; and if we revert to the nebulous condition, it is because the probabilities are really on its side. Our question is this: Did creative energy pause until the nebulous matter had condensed, until the earth had been detached, until the solar fire had so far withdrawn from the earth's vicinity as to permit a crust to gather round the planet? Did it wait until the air was isolated; until the seas were formed; until evaporation, condensation, and the descent of rain had begun; until the eroding forces of the atmosphere had weathered and decomposed the molten rocks so as to form solids; until the sun's rays had become so tempered by distance, and by waste, as to be chemically fit for the decomposition necessary to vegetable life? Having waited through these æons until the proper conditions had set in, did it send the fiat forth, "Let there be Life!"? These questions define a hypothesis not without its difficulties, but the dignity of which in relation to the world's knowledge was demonstrated by the nobleness of the men whom it sustained.

Modern scientific thought is called upon to decide between this hypothesis and another; and public thought generally will afterwards be called upon to do the same. But, however the convictions of individuals here and there may be influenced, the process must be slow and secular which commends the hypothesis of Natural Evolution to the public mind. For what are the core and essence of this hypothesis? Strip it naked, and you stand face to face with the notion that not alone the more ignoble forms of animalcular or animal life, not alone the nobler forms of the horse and lion, not alone the exquisite and wonderful mechanism of the human body, but that the human mind itself—emotion, intellect, will, and all their phenomena—were once latent in a fiery cloud. Surely the mere state-

ment of such a notion is more than a refutation. But the hypothesis would probably go even farther than this. Many who hold it would probably assent to the position that, at the present moment, all our philosophy, all our poetry, all our science, and all our art—Plato, Shakespeare, Newton and Raphael—are potential in the fires of the sun. We long to learn something of our origin. If the Evolution hypothesis be correct, even this unsatisfied yearning must have come to us across the ages which separate the primeval mist from the consciousness of to-day. I do not think that any holder of the Evolution hypothesis would say that I overstate or overstrain it in any way. I merely strip it of all vagueness, and bring before you, unclothed and unvarnished, the notions by which it must stand or fall.

Surely these notions represent an absurdity too monstrous to be entertained by any sane mind. But why are such notions absurd, and why should sanity reject them? The law of Relativity, of which we have previously spoken, may find its application here. These Evolution notions are absurd, monstrous, and fit only for the intellectual gibbet, in relation to the ideas concerning matter which were drilled into us when young. Spirit and matter have ever been presented to us in the rudest contrast, the one as all-noble, the other as all-vile. But is this correct? Upon the answer to this question all depends. Supposing that, instead of having the foregoing antithesis of spirit and matter presented to our youthful minds, we have been taught to regard them as equally worthy, and equally wonderful; to consider them, in fact, as two opposite faces of the self-same mystery. Supposing that in youth we had been impregnated with the notion of the poet Goethe, instead of the notion of the poet Young, and taught to look upon matter, not as "brute matter," but as "the living garment of God"; do you not think that under these altered circumstances the law of Relativity might have had an outcome different from its present one? Is it not probable that our repugnance to the idea of primeval union between spirit and matter might be considerably abated? Without this total revolution of the notions now prevalent, the Evolution hypothesis must stand condemned; but in many profoundly thoughtful minds such a revolution has already taken place. They degrade neither member of the mysterious quality referred to; but they exalt one of them from its abasement, and repeal the divorce hitherto existing between them. In substance, if not in words, their position as regards the relation of spirit and matter is: "What God hath joined together, let not man put asunder."

You have been thus led to the outer rim of speculative science, for beyond the nebulæ scientific thought has never hitherto ventured. I have tried to state that which I considered ought, in fairness, to be outspoken. I neither think this Evolution hypothesis is to be

flouted away contemptuously, nor that it ought to be denounced as wicked. It is to be brought before the bar of disciplined reason, and there justified or condemned. Let us hearken to those who wisely support it, and to those who wisely oppose it; and let us tolerate those, whose name is Legion, who try foolishly to do either of these things. The only thing out of place in the discussion is dogmatism on either side. Fear not the Evolution hypothesis. Steady yourselves, in its presence, upon that faith in the ultimate triumph of truth which was expressed by old Gamaliel when he said: "If it be of God, ye cannot overthrow it; if it be of man, it will come to naught." Under the fierce light of scientific inquiry, it is sure to be dissipated if it possess not a core of truth. Trust me, its existence as a hypothesis is quite compatible with the simultaneous existence of all those virtues to which the term "Christian" has been applied. It does not solve—it does not profess to solve—the ultimate mystery of this universe. It leaves, in fact, that mystery untouched. For, granting the nebula and its potential life, the question, whence they came, would still remain to baffle and bewilder us. At bottom, the hypothesis does nothing more than "transport the conception of life's origin to an indefinitely distant past."

Those who hold the doctrine of Evolution are by no means ignorant of the uncertainty of their data, and they only yield to it a provisional assent. They regard the nebular hypothesis as probable, and, in the utter absence of any evidence to prove the act illegal, they extend the method of nature from the present into the past. Here the observed uniformity of nature is their only guide. Within the long range of physical enquiry, they have never discerned in nature the insertion of caprice. Throughout this range, the laws of physical and intellectual continuity have run side by side. Having thus determined the elements of their curve in a world of observation and experiment, they prolong that curve into an antecedent world, and accept as probable the unbroken sequence of development from the nebula to the present time. You never hear the really philosophical defenders of the doctrine of Uniformity speaking of *impossibilities* in nature. They never say, what they are constantly charged with saying, that it is impossible for the Builder of the universe to alter His work. Their business is not with the possible, but the actual—not with a world which *might* be, but with a world that *is*. This they explore with a courage not unmixed with reverence, and according to methods which, like the quality of a tree, are tested by their fruits. They have but one desire—to know the truth. They have but one fear—to believe a lie. And if they know the strength of science, and rely upon it with unswerving trust, they also know the limits beyond which science ceases to be strong. They know best that questions offer themselves to thought, which science, as now

prosecuted, has not even the tendency to solve. They have as little fellowship with the atheist who says there is no God, as with the theist who professes to know the mind of God. "Two things," said Immanuel Kant, "fill me with awe: the starry heavens, and the sense of moral responsibility in man." And in his hours of health and strength and sanity, when the stroke of action has ceased, and the pause of reflection has set in, the scientific investigator finds himself overshadowed by the same awe. Breaking contact with the hampering details of earth, it associates him with a power which gives fulness and tone to his existence, but which he can neither analyse nor comprehend.

Special Questions

1. How many analogies has Tyndall used in this essay? Make a list of them, giving the page on which each appears.
2. How many different illustrations of Mill's methods can you find in the essay? Make a list, indicating page where each appears.
3. Make a list of the hypotheses mentioned by Tyndall. Tell whether each was verified positively or negatively and how each was verified. Give the page where each is discussed.
4. Find at least one good example of the complete method of explanation in Tyndall's essay, analyzing it into steps, as you were asked to analyze the examples in Chapter VIII.

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